# INVESTIGATING THE POTENTIAL FOR JACARANDA STREET TREES TO MITIGATE CLIMATE CHANGE IN TSHWANE, SOUTH AFRICA


**BY:**

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**DECLARATION**

**I declare that the research for the topic:**

**“Investigating the Potential for Jacaranda Street Trees to mitigate Climate Change in Tshwane, South Africa.” is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of a complete reference list.**

**Signature:** **Date: 08/02/2021**

**Ms. K C Mangena**

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# DEDICATION

I dedicate this study to my mother Professor Agnes Makhene, to my father Mr. Morris Mangena, to my big sister Pearl Makhene and to my husband, Bongani Ndaba.

## ACKNOWLEDGEMENT

First and above all, I would like to send gratitude to the Lord Almighty for carrying me through my studies and affording me the strength to see it to completion.

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## ABSTRACT

Climate Change poses a great risk to our future as species on Earth. The impacts thereof will have far reaching consequences on every aspect of our daily lives and ultimately on our ability to survive and thrive as humans. It is therefore important, particularly in urban areas where most of the human population live, for the investment of resources and expertise into mitigating these impacts and ensuring the resilience of urban areas. The urban forest provides climate change mitigation benefits for urban areas through carbon sequestration. In order to encourage investment and protection of the urban forest, this benefit must be quantified and afforded a monetary value. This study calculated the amount of carbon dioxide sequestrated by the Jacaranda mimosifolia street tree in the City of Tshwane and afforded this amount a monetary value in both South African Rands and American Dollars through the South African Carbon Tax Bill. This study followed the baseline study by Stoffberg (2006) looking at how much carbon dioxide had been sequestrated by the Jacaranda trees over the past 15 years post the baseline study and what monetary value do the trees now have through legislation that was not available during the baseline study. The study also observed the variables that may have affected the amount of carbon dioxide sequestrated by the trees. Although some areas saw a drop in the Total Carbon Dioxide Equivalent sequestrated since 2004, the total amount for the whole city remained stable. Through the Carbon Tax Bill, the value of these trees has increased significantly encouraging the municipality to invest in the maintenance and protection of the Jacaranda street trees in the City of Tshwane in order to preserve their carbon sequestration benefits.

**Key Words**: climate change mitigation, urban forestry, carbon sequestration

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## ACRONYMS AND ABBREVIATIONS

PPM – parts per million

GHGs – greenhouse gases

$CO_2$ – Carbon Dioxide

$CO_2$eq – Carbon Dioxide Equivalent

t – tonne

SCBH – Stem Circumference at Breast Height

SCGL – Stem Circumference at Ground Level

DBH – Diameter at Breast Height

DGL – Diameter at Ground Level

# CHAPTER 1: INTRODUCTION

## 1.1 Background

Climate Change has been observed in the planet's history with records showing a continuous change in climatic conditions over the last one thousand years (WMO, 2015). These changes are a result of both natural and anthropogenic processes. Natural climate change can result from variations in the Earth's orbit, variation in the chemical composition of the atmosphere as well variation in the circulation of the ocean currents and variations in the biosphere (WMO, 2015). Anthropogenic processes include deforestation, land clearing and the burning of fossil fuels (Blunden & Arndt, 2019). Natural climate change functions in a two-dimensional direction, moving back and forth in episodes of warming and cooling (WMO,2015). Anthropogenic climate change only functions in one-dimension, moving towards a warmer planet (WMO, 2015).

According to NASA (2019), atmospheric carbon dioxide ($CO_2$) levels were recorded at 412 ppm in July 2019. The mean global average temperature increased by 0.87 ˚C, with the warmest years within the 134-year record all occurring since the year 2000. The year 2015 is the warmest year on record (NASA, 2016). This increase in atmospheric $CO_2$ and the subsequent increase in global temperatures is mainly caused by activities that involve the burning of fossil fuels and the transformation of land through deforestation and vegetation clearing (Dhillon, Ajila, Kaur, Brar, Verma, Tyagi, & Surampalli, 2013). This one-dimensional shift in climatic conditions results in a number of consequences including melting ice caps and glaciers which then raise sea levels, drier land conditions, ocean acidification and an increase in extreme weather events such as floods, tropical cyclones, droughts, and heat waves (IPCC, 2007).

Africa is particularly vulnerable to the impacts of climate change because of its high exposure to global climate impacts and its limited ability to adapt to the changing climate (Niang, Ruppel, Abdrabo, Essel, Lennard, Padgham & Urquhart, 2014). South Africa is a semi-arid, warm country with significant variations in temperature and rainfall (DEA, 2011). The most significant risk in terms of climate change is therefore the country's ability to supply water from its limited water resources (DEA, 2011). Like many developing countries both in Africa and abroad, South Africa faces a number of challenges in terms of its ability to adapt to the changing climate (DEA, 2011). The population of South Africa is characterised by high Human Immunodeficiency Virus (HIV) and Tuberculosis (TB) infection rates. It also has a large number of its rural population moving to urban areas in search of better resources ending up in un-serviced informal settlements (UNDESA, 2013). These factors increase the population's vulnerability and exacerbate the impacts of climate change (DEA 2011).

In light of these factors, it is important for the country to develop sustainable mitigation and adaptation measures particularly in the wake of an increasingly urban population (The World Bank, 2016). The City of Tshwane Metropolitan Municipality is currently working on making the city more resilient and able to adapt to the changing climate. This can be seen in their Vision 2055 strategy which highlights the municipality's vision for a resilient city (City of Tshwane, 2013). One way of increasing a city's resilience is investing in green infrastructure such as urban forests. Green Infrastructure is described as any infrastructure that is beneficial to the environment and promotes sustainable development in an urbanised area (Biodiversity Advisor, 2019). Urban trees provide a number of benefits among which the ability to absorb and store carbon as biomass, plays an integral part in reducing atmospheric $CO_2$ (Stoffberg & van Rooyen, 2012). The urban forest in the City of Tshwane therefore has an important role to play in mitigating the impacts of climate change in the city (Stoffberg & van Rooyen, 2012).

The City of Tshwane is also commonly known as the "Jacaranda City" due to the large numbers of the *Jacaranda mimosifolia* trees occurring in parks and streets (Muthelo, 2009). The Jacaranda tree is not native to South Africa. Its origins can be traced to southern Bolivia and north-eastern Argentina (Invasive Species South Africa, 2016). It has subsequently been categorised as a category 3 invasive plant species according to the Conservation of Agriculture Resources Act, No. 43 of 1983 (DAFF, 2016). This is because the tree makes use of large amounts of water and out-competes indigenous plants (Invasive Species South Africa, 2016). Subsequently no one is permitted to plant or trade the tree and if it occurs in and around water sources, it is classified as a category 1 invasive species and must be removed immediately (DAFF, 2016). In the National Environmental Management: Biodiversity Act (Act 10 of 2004) Draft Alien and Invasive Species List of 2014, the Jacaranda tree is listed as a category

1b invasive species. Category 1b states “invasive species which must be controlled and whenever possible, removed and destroyed. Any form of trade or planting is strictly prohibited” (Biosecurity Advocacy Programme, 2015). Jacaranda trees located in urban areas of Gauteng, KwaZulu Natal, Limpopo, Mpumalanga and North West are exempted from the specifications of category 1b allowing for the preservation, replacement of the trees in urban areas. The Jacaranda tree’s contribution to reducing atmospheric $CO_2$ and mitigating climate is therefore important. Data provided by the City of Tshwane revealed that in 2004 the Jacaranda tree made up 17% of the city’s urban forest (Stoffberg, 2006). A baseline study by Stoffberg (2006) assessing the amount of carbon sequestrated by Jacaranda trees and the associated monetary value thereof in the City of Tshwane was conducted. At the time, the baseline study calculated the estimated US dollar value of the carbon sequestrated by the Jacaranda street trees by applying a hypothetical carbon value of “1 tonne of carbon is equal to 10 US$” (Stoffberg, 2006). This value was then converted into South African Rands by using the Rand to US Dollar exchange rate at the time of study of “1 US$ is equal to R6.59” (Stoffberg, 2006). The baseline study measured the stem circumference of 1525 Jacaranda street trees in 73 suburbs. The total carbon quantity for all the measured suburbs (73 suburbs) was estimated at 12 207.372 t C (Stoffberg, 2006). The total carbon quantity for all the suburbs of the City of Tshwane (114 suburbs) was estimated at 12 709.241 t C (Stoffberg, 2006). The baseline study presented a 10% reduction from the total carbon quantity providing an adjusted value of 11 384.317 t C. This deduction is based on variation between forest and urban carbon storage as stated in Stoffberg (2006).

The baseline study also provided a $CO_2$eq amount for all the suburbs in the City of Tshwane. The amount was estimated at a total of 46 642.916 t $CO_2$eq (Stoffberg, 2006). Similarly, to the total C, an adjusted total amount of 41 978.625 t $CO_2$eq was provided (Stoffberg, 2006). Using a hypothetical price of “1 tonne is equal to 10 US$”, the adjusted $CO_2$eq value was estimated at US$ 419 786, and the associated Rand value estimated at R2 766 391 (Stoffberg, 2006).

Using the data and results from the baseline study, this study first established whether the Jacaranda street tree population had changed since the baseline study was conducted. The City of Tshwane Metropolitan Municipality confirmed, through personal communication from Mr. B Dry on 24$^{th}$ of July 2019 that the Jacaranda street tree population had remained stable since the baseline study was first conducted. Secondly this study calculated and estimated the total Carbon, total $CO_2$eq quantities and determined the associated monetary values. However, this study only measured the stem circumference in 72 suburbs as the trees in Samcor Park had since been removed and replaced with a different tree species. This study calculated the Rand value of the total C and total $CO_2$eq amounts by applying the values provided in the South African Carbon Tax Bill (Republic of South Africa, 2019). The Carbon Tax, provided for by the South African National Treasury, stipulates that "1 tonne C is equal to R120 (Republic of South Africa, 2019). This value was then converted into US$ by assuming the "1 US$ is equal to R15" exchange rate relevant at the time of calculation. Lastly, this study assessed the health status of the Jacaranda street trees by observing for any pests and diseases, for any broken and/or dying branches, the interaction between the trees and infrastructure and the zoning of the areas where the trees are observed the impact of the surface as well on which the trees are growing. The health status was not assessed in the baseline study.

### 1.2 Problem Statement

According to the Intergovernmental Panel on Climate Change (2014) South Africa will see a temperature rise of between 2˚C and 3˚C in the interior and between 1˚C and 2˚C at the coast. Environmental impacts associated with a changing climate include an increased frequency of veld fires, an increase in the frequency of extreme whether events such as droughts and floods as well as rising sea levels which will threaten the survival of coastal communities (IPCC, 2014). It is therefore important that countries, and in particular South Africa, implement mitigation and adaptation measures in order to survive the changing climate.

Urban areas are major emitters of greenhouse gases and are highly vulnerable to the impacts of climate change such as droughts, heat waves, flooding, and pollution (IPCC, 2014). Cities therefore need to become active in mitigating climate change and identify adaptive measures that focus on the rethinking of the design of urban areas (IPCC, 2014). Incorporating urban forests into the urban design provides a mitigation and adaptation measure for climate change in the city. Trees are carbon sinks because they fix carbon through the process of photosynthesis thereby storing the carbon as biomass (Nowak, Greenfield, Hoehn & Lapoint, 2013). Trees and forests are part of the earths long-term carbon cycle and hold great carbon sink potential in both natural and urban forest systems. Like many cities, the City of Tshwane faces a number of challenges in terms of providing for an increasing population as well as meeting the needs of the economic sector while working to reduce poverty and inequality in the wake of a changing climate (SACN, 2014).

Climate change modelling for the City of Tshwane predicts that temperatures will increase between 4°C and 6.5°C by the start of the next century. It is projected that the city will receive less rain and experience warmer days (SACN, 2014). Extreme weather events such as droughts, heat waves, floods and hailstorms are expected to increase in frequency and intensity with the poorest of the city's population being affected the most (SACN, 2014). The City of Tshwane has adopted the Clean Development Mechanism (CDM), a mechanism based on the "polluter pays" principal to fund projects within the mechanism (City of Tshwane, 2011). The mechanism is adopted from the work done by the UNFCCC in 2005 and will benefit the city by bringing green and clean investments into the city (City of Tshwane, 2011). Such investments include investments towards projects that encourage carbon emission reduction, carbon emission prevention as well as carbon sinks and sequestration (City of Tshwane, 2011). Due to the fact that trees sequestrate and store carbon, they present an opportunity of investments for the CDM.

### 1.3 Purpose of the study

The purpose of the study is to measure and estimate the amount of carbon sequestrated by the *Jacaranda mimosifolia* trees in the City of Tshwane to show how this tree species contributes to urban forestry and ultimately how the urban forest is contributing towards mitigating the impacts of climate change. This will be achieved by making use of existing data from the baseline study to establish how many *Jacaranda mimosifolia* trees are still growing in the City of Tshwane and through the measurement of the stem circumference of the trees in the sample, determine how much carbon has been sequestrated by the Jacaranda trees. The study will also evaluate the health status of the trees by observing the presence of pests and diseases, the presence of broken and dying branches, the trees interaction with infrastructure and the zoning of the areas where the trees are growing as well as the impact of the surface on which the trees are growing. Finally, the study will provide recommendations for continued research and management of the existing *Jacaranda mimosifolia* tree population.

## 1.4 Research Objectives

The research objectives in this study are to:

1.4.1 Determine whether the *Jacaranda mimsifolia* street trees that were identified and measured in the baseline study are still growing in the relevant suburbs.

1.4.2 Measure the tree stem circumference at Breast Height and Ground Level and compare the data to that presented in Stoffberg (2006).

1.4.3 Calculate the mean carbon, total carbon and total carbon dioxide equivalent amounts for each suburb.

1.4.4 Calculate the current US dollar and Rand values of the total carbon and total carbon dioxide equivalent amounts.

1.4.5 Through observation, establish the health of status of the Jacaranda street trees by;

1.4.5.1 Determining whether the trees have any diseases and/or pests.

1.4.5.2 Describing the relationship between the Jacaranda trees and infrastructure.

1.4.5.3 Observe the impact of the surface on which the trees are growing on.

1.4.5.4 Determine whether the zoning of the areas in which the trees are growing has an impact on the pressures the trees encounter in the urban environment.

## 1.5 Significance of the Study

According to the IPCC (2007) anthropogenic climate change is one of the greatest challenges the human race will face in the near future. Urban areas, particularly those in developing countries, are predicted to suffer the most as the urban population continues to increase. This increase will further strain available natural resources. Droughts will continue to place great pressure on water resources and the ability of countries to produce food. Floods also pose a significant threat particularly in urban areas of Gauteng where drainage infrastructure is poor. Urban trees could also assist with heat waves and peak flow mitigation (Ferrini, Fini, Mori & Gori, 2020). This study will therefore contribute towards the knowledge of carbon sequestration through urban forestry and therefore the mitigation of these climate change impacts.

## 1.6. Ethical Considerations

The study was approved by the University of South Africa Ethics committee and permission was also obtained from the municipality (City of Tshwane). The study followed all the requirements needed to undertake a study so as to not harm the environment. (Ethics number: 2016/CAES/121)

## 1.7. Summary

This chapter provides context of the problems facing South Africa in terms of climate change and how urban forests provide a means to mitigate the impacts thereof. In this study the focus is on the *Jacaranda mimosifolia* street trees growing as part of the urban forest in the City of Tshwane. The chapter described carbon sequestration can be measured and presented in monetary values and compared to the baseline study. The next chapter will provide literature on climate change and its associated impacts internationally, nationally and locally (study area). It will also highlight the importance of the urban forest as a tool to mitigate the impacts of climate change through carbon sequestrations as well as highlight South Africa’s efforts in compiling policies to mitigate the impacts of climate change.

## 1.8. Chapter Breakdown

Chapter Two provides a literature review that looks at what climate change is and its impacts on a global and continental scale. The literature review then highlights the various impacts of climate change on areas around the world and more specifically on the study areas in South Africa. It finally introduces the scope of the study (Carbon sequestration by Jacaranda trees) and establishes the importance of this study in light of the benefits of carbon sequestration in terms of climate change.

Chapter Three provides the research design and method. This chapter explains how the data was collected and the rational of the method of data collection.

Chapter Four presents the data collected and analysis thereof in multiple formats (maps, tables and graphs) to begin to show the results of the study based on the objectives presented in chapter 3.

Chapter Five provided the results and conclusion of the study by comparing the results from the baseline study and those in this study. Lastly, providing recommendations for future studies about carbon sequestration.

# CHAPTER 2: LITERATURE REVIEW

## 2.1. Introduction

Climate change is defined by the United Nations Framework Convention on Climate Change (2011) as “change in the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period, typically decades or longer. It refers to any change in climate over time whether due to natural variability or as a result of human activity”. Anthropogenic (human) activities, particularly those that involve the burning of fossil fuels and the transformation of land and clearing of vegetation have, since 1880, caused a rise in global temperature (also known as global warming) of 0.8˚ C (Carlowicz, 2010).

The process of global warming is best described by looking at how a greenhouse functions. A greenhouse is a glass structure designed to trap heat to create an environment warm enough to support plant growth. The suns heat is trapped by the glass increasing the temperature in the greenhouse subsequently supporting plant growth (NASA, 2010). Similarly, greenhouse gases such as carbon dioxide, methane and nitrous oxides absorb heat. When the atmospheric level of these greenhouse gases is normal, they keep the planet warm enough for life to persist (IPCC, 2007). Normal levels, of carbon dioxide, are viewed in light of pre-industrial levels, which according to the National Oceanic and Atmospheric Administration (2020) never went above 300pmm. When the levels of atmospheric carbon dioxide increase in the atmosphere, they cause global warming (IPCC, 2007). According to NASA (2020) the amount of atmospheric carbon dioxide was at 415 ppm in October of 2020. The National Oceanic and Atmospheric Administration identified July 2019 as the hottest month on record (NOAA, 2019). As a result, the increase in temperature causes the melting of glaciers and ice caps which are threatening the survival of coastal communities by raising the sea level. NASA (2020) recorded a sea level rise of ± 4 mm in July of 2020. Other impacts resulting from higher temperatures include drier inland conditions, ocean acidification as well as an increased frequency of extreme events such as floods, droughts and tropical cyclones (Huber & Gulledge, 2011).

## 2.2. Climate Change in Africa

Africa, along with Madagascar, is the second largest continent with the second largest population after Asia (Niang, Ruppel, Abdrabo, Essel, Lennard, Padgham & Urquhard, 2014). The continent has the highest vulnerability to the impacts of climate change due to its high exposure to global climate change impacts as well as its limited ability to adapt to these changes (Boko, Niang, Nyong, Vogel, Githeko. Medany, Osman-Erasha, Tobo & Yanda, 2007). The past 50 to 100 years have seen an increase in temperature of 0.5 ˚C over most of Africa with minimum temperatures rising higher than the maximum temperatures (Nicholson, Nash, Chase, Grab, Shanahan, Verschuren, Asrat, Lèzine & Umer, 2013).

In northern Africa temperature is said to have risen significantly higher (due to anthropogenic activities) than the temperatures observed as a result of natural activities (Niang et al. 2014). The central and southern areas of eastern Africa have also experienced notable temperature increases since the 1980s (Niang et al, 2014). The Famine Early Warning System Network has, in support of Anya and Qui (2012), indicated that over the past 50 years an increase in annual temperatures has been recorded in Ethiopia, Kenya, South Sudan and Uganda. Additionally, rising near surface temperatures and a spike in extreme weather events have been recorded in areas that border the western Indian Ocean during the period between 1961 and 2008 (Vincent, Aguilar, Saindou, Hassane, Jumaux, Roy, Booneeady, Virasami, Randriamarolaza, Fanirantsoa, Amelie, Seeward & Montfairx, 2011b).

Projections indicate that temperatures in Africa will continue to increase faster in the 21$^{st}$ century (Meehl, Stocker, Collins, Friedlingstein, Gaye, Gregory, Kitch, Knitti, Murphey, Noda, Raper, Wateerson, Weaver & Zhao, 2007). The tropics, particularly tropical West Africa, are estimated to experience a rise in temperature within one to two decades, an estimate earlier than global figures due to the region's small variability in climate (Niang et al, 2014). Southern Africa is said to likely see an increase ranging between 3 ˚C and 4 ˚C by the end of the 21$^{st}$ century (Salliman & Roekner, 2008).

Areas along the Mediterranean coast in Algeria and Tunisia reported an extreme decline in precipitation in winter as well as at the start of spring with more than 330 dry days (days with less than 1mm of rainfall per day) during the period between 1997 and 2000 (Barkhodarian, von Storch & Bhend, 2013).

The last three decades saw rainfall reductions in eastern Africa. The likely cause was identified as increased convection over the Indian Ocean resulting in a drying effect over the land surface (Williams & Funk, 2011). Additionally, the north-eastern part of the Sahara recorded between 40 and 50 heat wave days during the period between 1989 and 2002 (IPCC, 2014). Predictions state that heat wave days will increase during the 21st century (Niang et al, 2014). Extreme weather events will also become more frequent in the Guinea Highlands and the Cameroon mountains (Haensler, Saeed and Jacob, 2013). In southern Africa reductions in summer rains were recorded in Namibia, Angola extending all the way to Congo (New, Hewitson, Stephenson, Tsiga, Kriger, Manhique, Gomez, Coelho, Masisi, Kululanga, Mbambalala, Saleh, Kanyanga, Adosi, Bulane, Fortunata, Mdoka & Lajoie, 2006).

The lack of equitable socioeconomic benefits limit Africa's resilience and ability to adapt to these changes. Nighty eight percent of agriculture in the sub-Saharan area relies on the presence of reliable precipitation (Niang, et al, 2014). Urbanization enhances the effects of climate change as people leave their rural homes to seek better resources in urban areas. The United Nations Department of Economic and Social Affairs: Population Division (2012) predicted that the urban population in Africa would increase threefold by the year 2020. African countries have some of the highest urbanization rates in the world with many of these areas arising unplanned. The result is an increase in informal settlements which are characterised by inadequate housing, extreme poverty and inadequate service delivery (UN HABITAT, 2008). Henderson, Storeygard & Deichmann (2016) state that as the climate continued to change, increasingly people would abandon their rural lifestyles for urban ones placing more pressure on declining natural resources.

## 2.3. Impacts of the changing climate in Africa.

### 2.3.1. Famine

In 2016, severely low levels of rainfall were measured during the short rains season (October – December). The situation was particularly acute across Somalia, southern and south-eastern Ethiopia as well as northern and coastal Kenya (UNICEF, 2016). The 2016 drought was worse than the 2010 to 2011 drought due to several factors. This was the third consecutive drought year in the region with a number of severely low food production years resulting in people's ability to cope with another such shock diminishing drastically (UNICEF, 2016).

A larger region than that of the previous drought was seen to be suffering from intensifying conflicts caused by the
reduced levels of access to basic needs, increased refugee numbers and increased levels of communicable diseases such as cholera (UNICEF, 2016).

Ethiopia continued to battle the residual impacts of the 2015/2016 El Niño which caused a drought, resulting in below average autumn rains in the southern and south-eastern parts of the country (UNICEF, 2016). UNICEF (2016) estimated that 9.2 million people would need support to access safe drinking water. It was also estimated that roughly 1.9 million people would need livestock support and an estimated 300 000 children between the ages of 6-59 months would need treatment for severe malnutrition in 2017 (UNICEF, 2016).

On the 10th of February 2016, the Kenyan government declared a national drought emergency. The government stated that 23 out of 47 counties in the country had been affected by the drought (UNICEF, 2016). The number of people who were now experiencing food insecurity had doubled from 1.3 million to 2.7 million (UNICEF, 2016). Roughly 357 285 children and pregnant and lactating women were severely malnourished (OCHA, 2017). Maize production in coastal areas had dropped by 99% as compared to the recorded long-term average. People now had to travel further to find water and roughly 175 000 children were not attending early pre-primary and primary school mainly as a result of the drought (UNHCR, 2017).

The latest food security and nutrition analysis by the FAC-Managed Food Security and Nutrition Analysis Unit (FSNAU) as well as the Famine Early Warning System and Nutrition Network indicated that the number of people in need of humanitarian aid in Somalia had risen from 5 million to 6.2 million in the year 2016. This number rose during the period between February and June of 2017.UNICEF (2016) indicated that 185 000 children were severely malnourished. This number was set to increase to 270 000 (UNICEF, 2016). Roughly 30 000 children in Puntland and Somaliland had dropped out of school as a result of the drought (UNICEF, 2016).

### 2.3.2. Vector-borne diseases

Climate change has a direct impact on the development of arthropod vectors as is currently observed in ticks and mosquitoes (Beugnet & Chavel-Monfray, 2013). The

World Health Organization (WHO) estimates that one sixth of sicknesses and disabilities world-wide are due to vector borne diseases with more than half the world's population being at risk (Campbell-Lendrum, Manga, Bagayoko & Somerfeit, 2015).More than one billion people are infected each year and of that billion, one million of them die from vector borne diseases such as Malaria, Dengue Fever, Schistosomiases, Leishmaniosis, Changa disease and African Trypanosomiases (Campbell et al, 2015).

Long term anthropogenic climate change affects the natural cycle of vector-borne diseases like malaria by extending the disease transmission from annual to decadal (Campbell et al, 2015). Malaria is an important disease because it has a global distribution and causes a significant health burden particularly in developing countries where it is more common (Caminade, Koat, Rockolov, Tompkins, Morse, Colón-González. Stenlund, Martens & Lloyd, 2014). These countries are particularly vulnerable due to low levels of socioeconomic development and low coverage of health services (Campbell et al, 2015).

### 2.3.3. Conflict

Climate change can be seen as a multiplier of existing threats, intensifying existing tensions and instability. The main issue is that climate change threatens to overburden countries that are already prone to conflict (EN, 2008).

Conflict mainly rises from competition for natural resources. This can be explained through the following examples.

- Conflict over natural resources such as water
  Climate change affects rainfall, and the availability of freshwater is reduced by between 20% to 30%. This results in agricultural productivity reduction and threatens food security. Diminishing water resources can therefore lead to civil unrest and enhance existing conflicts where the access to resources is politicized (EN, 2008).
- Loss of territory and boarder disputes
  Rising sea levels threaten coastal areas and could submerge entire small island countries. This could lead to conflict over maritime boarders and other conflicts over territory. Migration threatens political stability as desertification forces people to move (UNDP, 2012).

- Tension over energy supply

  Energy supply poses one of the greatest risks of conflict. Conflict can arise over access and control of energy resources. Much of the world's hydrocarbon reserves are located in countries that are most vulnerable to climate change impacts and will therefore further exacerbate tensions.

Africa is particularly at risk because of its low adaptive and resilience capability. For example, in Sahel, north of Africa, drought is set to increase. Water will become scarce and land degradation will lead to loss of 75% of arable land (UNDP, 2012). Agricultural areas in the Nile Delta are at risk from sea level rise. In southern Africa droughts have led to poor harvests and threatened food security. These factors could lead to conflict on the African continent (UNDP, 2012).

**2.4. Climate change in South Africa**

South Africa covers a surface area of approximately 1 219 602 $km^2$. It stretches from latitude 22˚S to 35˚S and from a longitude 17˚E to 33˚E (South African Government, 2016). The country has a semi-arid, subtropical climate regulated by both the Indian and Pacific oceans which surround the country on three sides (South African Government, 2016). The country receives a mean average rainfall of 464mm per annum (South African Government, 2016). The country is a water scarce country with a growing population that is said to face water challenges in the near future as the climate changes (Dennis & Dennis, 2011). It is estimated that temperatures will rise by 1.5 ˚C along the coast and between 2˚C and 3˚C inland by the year 2050 (Dennis & Dennis, 2011). Similarly, to other developing counties, South Africa faces a number of challenges in terms of its high vulnerability to the impacts of climate change. The agricultural sector is said to experience a greater water demand as rivers and dams dry up as a result of higher temperatures.

They will also face more pest and disease incidences (Ziervogel, New, van Graden, Midgley, Taylor, Hamann, Stuart-Hill, Myers & Warbuton, 2014). Health risks will also increase in a warmer climate. Illnesses such as heat stress, communicable diseases like influenza and vector borne diseases such as malaria will become a major concern in a warmer climate (Ziervogel et al, 2014).

According to The World Bank (2016) 65% of the South African population is urbanized with this number increasing as the impacts of climate change intensify.

The South African population is characterised by high levels of Human Immunodeficiency Virus (HIV) and Tuberculosis (TB) infections. It also has high levels of rural migration into urban areas, subsequently leaving a large number of the population living in informal, none-serviced settlements on a subsistence income. These factors enhance the country's vulnerability to the impacts of climate change (Department of Environmental Affairs, 2011). Historically, the South African economy was built on an energy intensive industry that was powered by low-cost, coal fired energy (Department of Environmental Affairs, 2014). As a result, the country has one of the highest levels of GHGs when compared to other developing countries (Nhamo, 2011). The country is among the top 20 emitters of GHGs globally, contributing about 1.1% of global emissions (EcoWatch, 2015). It is therefore important that the country implements measures to reduce its emissions not only for the South African population but also in terms of its responsibility to the international community (Department of Environmental Affairs, 2013).

South Africa is party to the Kyoto Protocol, a treaty that "commits its parties by setting internationally binding emission targets" (UNFCC, 2014). The protocol was adopted on the 11th of December 1997 in Japan. It was then enforced on the 16th of February 2005 (UNFCC, 2014). Although not an annex 1 country, South Africa has committed itself to developing policies that encompass the overall objective of international climate change treaties such as the Kyoto Protocol (Department of Environmental Affairs, 2011). The South African National Climate Change Response Green Paper was published as the country's first step in responding to climate change through legislation. The paper establishes the country's commitment to limit the global average temperature increase to below 2˚C as per the negotiations of the UNFCCC (Department of Environmental Affairs, 2010). It also highlights the government's vision for an effective and efficient response to climate change as well as the long-term steps towards an economy and society that is resilient to the changing climate and able to function at lower carbon emissions (Department of Environmental Affairs, 2010). The South African climate change objective therefore aims to achieve the environmental right as per section 24 of the country's constitution which provides everyone the right to an environment that is not harmful.

The department states that this can be achieved by "making a fair contribution to the global effort to achieve the stabilisation of GHG concentration in the atmosphere at a level that prevents dangerous anthropogenic interference with the climate" (Department of Environmental Affairs, 2010). The Department of Environmental Affairs goes further to explain that this is done to manage unavoidable and detrimental impacts of climate change and these interventions must build and sustain South Africa's social, economic and environmental resilience and emergency response capacity (Department Environmental Affairs, 2010). The Green Paper goes further by highlighting how the climate change response strategy aims to achieve the country's climate change objective. It does this by setting strategic objectives that include strategic risk reduction and management; mitigation actions with significant outcomes; sectoral responses; policy and regulatory alignment; informed decision making and planning; integrated planning; technology research; development and innovation; facilitated behaviour change; behaviour change through choice, as well as resource mobilisation (Department of Environmental Affairs, 2011).

Following the Green Paper, the White Paper was published in 2011 and subsequently resulted in the development of the National Climate Response Policy, a framework that provides the means for a climate response through a strategic view of both mitigation and adaptation (Department of Environmental Affair, 2014). In an effort to achieve the objectives set out in the policy, in particular those that encourage the transition into a low-carbon economy as well as meeting the global commitment to reduce GHG emissions, the national treasury released a press statement indicating that all new car sales would be subject to a carbon tax effective from the 1$^{st}$ of September 2010 (National Treasury, 2010). The tax was based on the "polluter pays" principle with the aim of influencing behavioral change with regards to climate change impacts (National Treasury, 2010). On the 2$^{nd}$ of November 2015, the South African government released the draft Carbon Tax Bill for comments (Ensor, 2015).

The Bill gives a marginal carbon tax rate of R120 for each tonne of $CO_2$ and the first phase of its implementation was set to run up until the year 2020 (Ensor, 2015). The policy lists the planting of trees as a mitigation option with the eventual aim of each household in the country having at least one tree. This policy was envisaged to be implemented over the next 20 years (DEA, 2014).

According to the South African National Treasury (2014), a carbon offset is an (external) investment that allows a firm to access GHG ($CO_2$ equivalent) mitigation options in a manner that is cheaper than investments in its own operation." Carbon offsets typically involve investment in specific projects or activities that reduce, avoid, or sequester emissions" (DEA, 2014). The National Climate Response Policy lists the planting of trees as a mitigation option (DEA, 2014). This mitigation option is particularly important due to the benefits provided by trees particularly in urban areas where atmospheric levels of $CO_2$ are at their highest as compared to the rest of the country (Konijnendjik, Annerstedlt, Nielsen & Maruthaeeran, 2013). Among these benefits one of the most significant in terms of climate change is the tree's ability to absorb carbon through photosynthesis, effectively fixing the carbon as biomass (Konijnendjik et al, 2013). This process allows for a natural solution to mitigating climate change as well as presenting an opportunity for offset investments through planting and maintaining trees (South African National Treasury, 2014).

In 2015 South Africa became a signatory of the Paris Agreement that was established at the Conference of the Parties (COP15) held in Paris. The Paris Agreement elevated the importance of climate change adaptation by providing an extensive guideline on how countries can make adaptation a priority (Republic of South Africa, 2019). In May of 2019, the South African Government published the draft Climate Change Adaptation Strategy (NCCAS) (Republic of South Africa, 2019). The strategy highlights the country's common vision on climate change resilience and adaptation as well as outlining the priority areas from which to achieve this vision (Republic of South Africa, 2019). The NCCAS serves as a means to fulfil the country's international obligation as per the Paris Agreement under the UNFCCC (Republic of South Africa, 2019).

### 2.5. Urban Forestry and Carbon Sequestration

According to the United Sates Department of Agriculture (2016), the urban forest can be defined as all the trees within the urban landscape including the different components (soil and understory flora).

The urban forest is made up of trees on sidewalks, in residential properties as well as in parks (United States Department of Agriculture, 2016). With an increase of urbanization that has seen cities worldwide, growing in size and number, the need for better management of urban spaces has become urgent (Borelli, Conigliaro & Pineda, 2018).

The urban forest provides several benefits that support this endeavor. Some of the benefits include cleaner air quality, energy conservation in homes and buildings, noise reduction, improved quality of health and carbon sequestration (United States Department of Agriculture, 2016). Urban forests also provide a number of psychological benefits including a perceived increase in neighborhood safety, increase of pride in the community, reduced stress and improved physical health (Gauld, 2015). Trees and forests are part of the earths long-term carbon cycle and hold great carbon sink potential in both natural and urban forest systems Urban areas in the United States make up 3% of the total land area and are home to 81% of the total population. The trees in these areas have been found to sequester 14% of the carbon sequestrated by forests in the United State (Mcpherson, Xiao & Aguaron, 2013). Annually, the benefits provided by urban forests through air pollution removal, carbon sequestration, lowered energy use by buildings resulting in adjusted power plant use, are estimated to amount to 18.3 billion US dollars (Nowak & Greenfield, 2018).

The potential for urban forests to mitigate these impacts has not been adequately investigated and published in literature, however, Onyekwelu (2010) provides an insight on the benefits of urban forests in West Africa. The West African population has quadrupled in the last five decades with the population growing from 64.1 million in 1950 to 239.5 million and 272.5 million in the year 2000 and 2005 respectively (Onyekwelu, 2010). Onyekwelu (2010) stated that it is projected that the population will reach 382.9 million in 2020 (Onyekwelu, 2010). Similarly, to the rest of the world, the trend of higher populations in urban areas has been seen in West African cities along with the associated problems such as soil erosion, air and water pollution as well as climate change impacts. Urban forests provide the most attainable strategy to address these issues (Onyekwelu, 2010). Some tangible benefits of urban forests in West African cities include wood for fuel and construction, food security, medicinal plants and spiritual and cultural benefits (Onyekwelu, 2010) Most of the large cities in West Africa are characterized by high congestion and consequently high pollution levels. The research of the benefits of urban trees in this regard would therefore serve to enhance and improve urban area management in West Africa. Sixty-five percent of the population in Southern Africa lives in urban areas. Southern Africa is also the most urbanised region in Africa (Schäffler & Swilling, 2013).

Considering this, urban forests have an important role to play in mitigating the impacts of climate change, in particular mitigating these impacts through carbon sequestration.

Similarly, to the rest of Africa, research on the benefits of urban forests in South African urban areas is still lacking. However, some research is available. This research is centered around two of the country's major urban areas namely Johannesburg and Tshwane. Johannesburg is home to a third of the country's population and is said to be one of the biggest man-made forests in the world, boasting around 10 million trees (Schäffler & Swilling, 2013). The tree planting boom in Johannesburg began in the 19th century in response to the pollution and dust released due to intense mining activities during the "Gold Rush" (Schäffler & Swilling, 2013). Over the years the trees have also mitigated the urban heat island phenomenon and provided carbon sequestration benefits for the city (Schäffler & Swilling, 2013). In the City of Tshwane, Stoffberg and van Rooyen (2012) have highlighted some of the benefits provided by Jacaranda Street trees. These include heating and cooling energy saving in buildings and the mitigation of the urban heat island phenomenon (Stoffberg & van Rooyen, 2012). These urban forests also provide physical and psychological benefits by giving people a sense of place and well-being (Shackleton & Blair, 2013). The study by Stoffberg and van Rooyen (2012) places focus on one of the more pressing benefits of urban forests in terms of climate change; the benefits provided through carbon sequestration.

Carbon sequestration is one of the most important benefits of urban forests in terms of climate change. Mitigation involves measures that stop the negative impacts before they occur, while adaptation entails measures to adjust or adapt after the impacts have occurred. Carbon sequestration provides a mitigation option in that the carbon dioxide is absorbed before and can cause global warming and the subsequent impacts thereof. (European Environmental Agency, 2021) Carbon sequestration takes place during photosynthesis as plants absorb carbon dioxide and convert the carbon into biomass and release oxygen as a by-product (Ugle, Rao & Ramachandra, 2010). Approximately 50% of the dry biomass is carbon. This effectively makes trees carbon sinks (Ugle, Rao & Ramachandra, 2010).

Carbon dioxide is a particularly important greenhouse gas especially in urban areas where the burning of fossil fuels releases large amounts of the gas (Ugle, Rao & Ramachandra, 2010). The Kyoto Protocol to the UN Framework Convention of Climate Change (UNFCCC) encourages the consideration of carbon sinks as a mitigation tool for climate change.

The urban forest therefore has an important role to play in addressing climate change at a regional level (Ugle, Rao & Ramachandra, 2010). This is supported by a study done be Nowak et al. (2013) were urban forests in 28 cities in the United States were found to have sequestrated 25.6 billion tonnes of carbon annually with an estimated monetary value of ± $20 billion.

In South Africa, this has become particularly important as urban areas continue to grow and consequently also suffer the impacts that accompany urban growth. South Africa is responsible for almost half (40%) of the continents GHGs output. Egypt, Algeria, Nigeria, Libya, Morocco and the rest of Africa only contribute 10%, 7%, 5%, 3% and 18% respectively (Urban Earth, 2012). According to the State of Energy in South African cities report of 2011, South African cities use 44% of the electricity produced by the country. These cities include Johannesburg, Ekurhuleni, City of Cape Town, eThekwini and City of Tshwane, all of whom are estimated to releases ± 23, 22, 21, 19 and 19 million tonnes of GHGs respectively (Urban Earth, 2012). Of these cities, three of them are found in the Gauteng province. Gauteng is the smallest province but is home to the highest population (12 272 263) in the country (Statistics South Africa, 2011). For the purpose of this study, the focus will be on the City of Tshwane.

### 2.6. Urban Forestry in the City of Tshwane

The City of Tshwane is a district municipality in the Gauteng province (SACN, 2014). It is one of the six largest municipalities in South Africa and the second largest in the Gauteng province (SACN, 2014). The municipality is home to a population of 2.9 million people. According to Stoffberg (2006) the City of Tshwane Metropolitan Municipality implemented a process between 2002-2008 of planting 115 200 indigenous street trees in the urban areas of Atteridgeville, Ga-Rankuwa, Mabopane, Mamelodi, Soshunguve, Temba and Winterveld. Calculations estimated that by 2032 these trees will have absorbed 54 630 tonnes of carbon amounting to a value of over US$2 million (Stoffberg, 2006).

#### 2.6.1. *Jacaranda mimosifolia* Street Trees in the City of Tshwane

The municipality is also fondly known as the “Jacaranda City” due to the large number of *Jacaranda mimosifolia* trees planted in parks and on the sidewalks in the city (Muthelo, 2009). According to Stoffberg, (2006), in 2004, 17% of the urban trees (195 789) in the City of Tshwane were identified as the Jacaranda tree (33 630) thus making the tree a valuable asset in the quest to mitigate climate change through carbon sequestration.

The *Jacaranda mimosifolia* tree is native to south Bolivia and northeastern Argentina. It is planted in many parts of the world for its aesthetic value (Invasive Species South Africa, 2016). The tree sprouts a haze of beautiful violet flowers during the summer months (Muthelo, 2009). However, in South Africa the tree has been listed as a category 3 invasive species because it competes with indigenous plants particularly around water sources where it uses large amounts of water (Invasive Species South Africa, 2016). The category 3 listing states that species found under this category may not be planted or traded anymore without special permission and existing plants must not be allowed to spread. If the tree is found within any water courses, it must be considered a category 1 invasive species and be removed immediately (DAFF, 2016). In the National Environmental Management: Biodiversity Act (Act 10 of 2004) Draft Alien and Invasive Species List of 2014, the Jacaranda tree is listed as a category 1b invasive species. Category 1b states "invasive species which must be controlled and whenever possible, removed and destroyed. Any form of trade or planting is strictly prohibited" (Biosecurity Advocacy Programme, 2015). Jacaranda trees located in urban areas of Gauteng, KwaZulu Natal, Limpopo, Mpumalanga and North West are exempted from the specifications of category 1b allowing for the preservation, replacement of the trees in urban areas. Although listed as an invasive species, the tree plays an important role in the city's history and is a valuable part of its heritage. It is therefore protected as a natural heritage resource under the National Heritage Resources Act, No. 24 of 1999 (Republic of South Africa, 1999). According to Vollenhoven (2020) the cultural value "is embodied in the place itself, its fabric, setting, use, associations, meanings, records, related places and related objects". This encompasses the value of Jacaranda trees to the people of Tshwane. The cultural value is also viewed in terms of when the trees were first introduced to Tshwane (Vollenhoven, 2020). The social value refers to "a sense of place, its spiritual, political and cultural connotations.

The scientific value is viewed in terms of the environmental benefits (Vollenhoven, 2020).

The Jacaranda tree plays an important role in mitigating the impacts of climate change through carbon sequestration. In 2004 a study was done in response to the City of

Tshwane's request to provide a monetary value for the Jacaranda tree (Stoffberg, 2006). As carbon sequestration is one of the most important benefits of a tree, the aim of the study was to provide an estimate of the carbon sequestrated by the Jacaranda street trees in the City of Tshwane and provide a monetary value thereof (Stoffberg, 2006). The stem circumference of 1525 Jacaranda street trees was measured in 73 suburbs in order to determine the amount of carbon absorbed at the time (Stoffberg, 2006). The study found that the trees had absorbed an estimated 11 438.317 tonnes of carbon which had a value based on the exchange rate at the time of US$1.00 = R6.59, amounting to R2 766 391 (Stoffberg, 2006).

Urban forests face a number of challenges which include disease, pests and in an urban setting, their relationship with infrastructure. It has been noted that a substantial number of Jacaranda trees have been dying since 1998 in the City of Tshwane suburb of Brooklyn (Coetzee, Mainconwitz, Muthelo & Wingfield, 2015). One of the causes of death has been identified as root rot, a disease apparently caused by the *Garnoderma* species (Hennessy & Daly, 2007). The *Ganoderma* genus is found in the *Ganodermateceae* family, a group of fungi. The fungus causes the roots of woody plants to rot through the decomposition of lignin and cellulose (Nahar, Yusuf, Ismail, Tan & Mondal, 2013). The infection develops at the bottom of the plant, followed by the development of growths known as "brackets" in the advanced stages of the infection. Finally, the infection causes the trees' death (Hennessy & Daly, 2007). In 2016, South Africa initiated a project to improve surveillance and identification of pest risk to tree health (Paap, de Beer, Migliorini, Nel and Wingfield, 2018). During a routine surveillance in the KwaZulu-Natal Botanical Garden in Pietermaritzburg in 2017, the *Platanus xacerifolia* trees showed symptoms of the "ambrosia" beetle attack (Paap et al, 2018). The tiny beetle (also known as the polyphagous shot hole borer)

is native to Southeast Asia where its damage has not been severe as the trees have evolved with the beetle-fungus complex and have resistance to them (FABI, 2019). The beetle is about 2mm in length carries a number of fungal species when it infests a living tree (de Beer, 2018). One of these fungi, *Fusarium euwallacea*, which has been seen to permanently stay with the beetle, can eventually kill a beetle infested tree (FABI, 2019). The beetle devastated trees in California, USA and Israel after it was introduced in the early 2000s (de Beer, 2018). Since it was first discovered in KwaZulu-Natal, the Forestry and Agriculture Biotechnology Institute (FABI) has confirmed the presence of the beetle in eight provinces with the exception, as of March 2019, of Limpopo (FABI, 2019). The most visible impact of the invasion in South Africa is in the urban forest on streets, parks and gardens (FABI, 2019). Many trees have died in Sandton, George and Knysna with reports of the impact in Sedgefeild, Bloemfontein, Ekurhuleni, Pietermaritzburg and Durban becoming worse (FABI, 2019). The most common trees dying in South Africa include English Oak, Chinese Maple, Japanese Maple, Boxelder and Sweetgum (FABI, 2019). The *Jacaranda mimosifolia* has been identified as a non-reproductive host of the beetle by FABI (FABI, 2019).

The urban forest also has a complicated relationship with infrastructure. Trees can damage powerlines, cause power outages and fires (Most & Weissman, 2012). Their roots can also damage sewer pipes, septic tanks, parking lots and curbs (Northrob, 2013). The process of building infrastructure disrupts and manipulates soil in such a way that it changes the properties of the soil. These changes negatively influence the growing conditions of the trees (Randrup & Mcpherson, 2003). Yu, Hu, Cui, Chen and Wang (2019) state that the handling of soil results in compacting which depletes the carbon and nitrogen storage by blocking air gas exchange. The study by Yu et al. (2019) also found that pavements changed the bacterial community composition and reduced the bacteria diversity at the topsoil. Micro-organisms also have an important role to play in plant growth. The characteristic of the microbial community is also determined by the depth in the soil (Yu et al, 2019). Where the soil is covered by natural vegetation, microbial biomass and enzyme activity is decreased with depth in the soil. Under impervious pavement surfaces, these characteristics increased with depth in the soil (Yu et al, 2019). Randrup and Mcpherson (2003) describe how street and pavement surfaces can also affect soil humidity. The surfaces stop evaporation from taking place in the soil, resulting in roots being attracted to the top layer of soil. This subsequently causes cracks in street and pavement surfaces (Randrup and Mcpherson, 2003).

Irrigation only heightens this problem, further encouraging roots to grow in the top layer of soil (Randrup and Mcpherson, 2003). Some cities employ crown pruning to control root growth and manage the conflict with infrastructure. However, significant crown pruning may have a detrimental impact on the overall tree health (Randrup and McPherson, 2003).

Site selection also plays a vital role in the tree's overall health outlook. Trees that grow in areas prone to high pedestrian and vehicular traffic often require more maintenance (Community Planning Extension Organisation, 2020). Trees in industrial areas are exposed to high pollution that negatively affects their lifespan (Gheorghe & Ion, 2011).

Electric infrastructure such as power lines, traffic lights and telephone lines often come into conflict with trees. Municipalities spend millions trimming and even removing trees that cause such conflicts (Most and Weissman, 2012). Many cities employ "topping" to manage this conflict. Topping entails removing the crown of the tree. This process damages the tree and leaves it vulnerable to insect infestation and disease. This trimming also reduces the inherent benefits of trees with regards to climate change (Most & Weissman, 2012).

As a major contributor of the urban forest in the City of Tshwane, it is therefore important to determine how much carbon have the Jacaranda street trees sequestrated since the baseline study and provide the monetary value thereof in light of the South African Carbon Tax as well as provide a Dollar value as a globally utilised and recognized currency and finally evaluate the current health status of the trees in order to recommend further investments for the protection and conservation of the trees.

# CHAPTER 3: RESEARCH DESIGN AND METHOD

## 3.1. Introduction

The purpose of this chapter is to describe the research design and method used in this study. The research design and method are justified with a detailed explanation of the way they were used for each component in the study. This chapter also sets out the study area, the City of Tshwane, highlighting its physical and climatic features.

## 3.2. Study area

The City of Tshwane is a district municipality located in the Gauteng province. It is home to a population of 2.9 million people (Stats SA, 2011). The municipality is located in a summer rainfall region. The region received an average of 324 mm of rain between January and September of 2019 (South African Weather Service, 2019). The average maximum and minimum humidity values between January and September of 2019 were 75% and 24% respectively (South African Weather Service, 2019). The average maximum and minimum temperatures between January and September 2019 were 26 ˚C and 11 ˚C respectively (South African Weather Service, 2019). Two of the seven biomes are found in Gauteng with the City of Tshwane having both grassland and savanna biomes adequately represented (City of Tshwane, 2005)

Figure 3.1 shows the suburbs in which Jacaranda street trees were measured in the City of Tshwane.

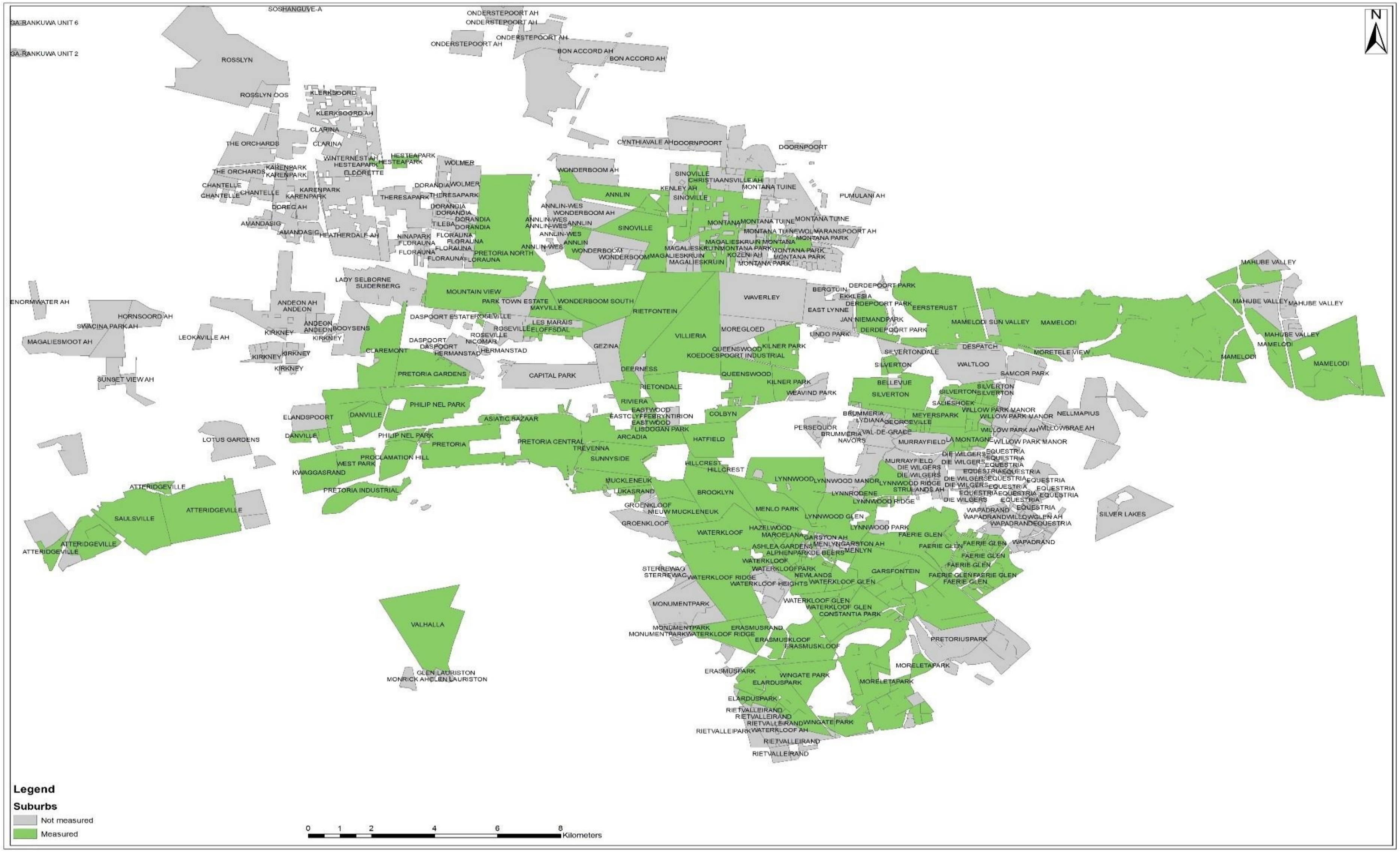


Figure 3.1: Map showing the suburbs in which *Jacaranda mimosifolia* street trees were measured in the City of Tshwane.

### 3.3. Research design

The research design is a plan of how the study was implemented. It lists all the steps in which the researcher collected, measured and analysed the data (Gray, Grove & Sutherland, 2017). The study followed a non-experimental design because the researcher did not manipulate the sample but aimed to describe the data and explained its relationship with the phenomena in question (Gray et al, 2017). The study was quantitative because the researcher used systematic techniques to investigate and observe the *Jacaranda mimosifolia* street trees by means of mathematical and statistical investigations.

### 3.4. Research method

The research method includes a description of the method used in conducting the study with a focus on the population, sample and sampling method, data collection, data analysis and validity and reliability/examinable.

#### 3.4.1. Population

A population is a well-defined data set that has specific properties that the researcher is interested in (Mouton, 2014). A total number of 33 630 Jacaranda street trees were identified in Stoffberg (2006). This total is based on a census completed by the City of Tshwane Metropolitan Municipality in the late 1990s as well as a tree-planting database initiated in 1995. The City of Tshwane Municipality confirmed, through personal communication with Mr. B Dry (24 July 2019), that the Jacaranda street tree population has remained stable since the baseline study was undertaken. This study has therefore made use of the same total Jacaranda numbers as those provided in the baseline study. In the baseline study 1525 Jacaranda trees in 73 suburbs were measured and observed. In this study 1540 Jacaranda street trees were measured and observed in 72 suburbs, one suburb less than the baseline study as the trees in Samcor park have since been removed and replaced with a different tree species.

#### 3.4.2. Sample and sampling method

Sampling refers to the process of selecting a portion of the designated population to represent the entire sample (Edmonds & Kennedy, 2013). A test sample was conducted in the baseline study in order to determine the number of trees that had to be measured in each suburb. The stem circumference of 20 trees per street in 13 suburbs were measured (Stoffberg, 2006). The test sample presented a low percentage error showing that 20 trees per street would provide a statistically representative sample for the mean stem circumference of *Jacaranda mimosifolia* street trees in the City of Tshwane (Stoffberg, 2006). Consequently, this study followed suit and used the 20 trees per street representative sample principle for gathering field work tree data.

The inclusion criteria for the study was:

- The trees measured had to be *Jacaranda mimosifolia*.
- The trees must be measured in the same suburbs and streets as those measured in the baseline study.
- If the street measured in baseline study does not have the required representative sample (20 trees), the balance is measured in the closest street to the original street in the same suburb.

The following table shows the streets measured in the baseline study that could not be measured in this study due to trees being removed. As indicated above, if the trees in the street measured in the baseline study had less than 20 trees, the balance was measured in an adjacent street in the suburb. Some of the streets measured in the baseline study had no Jacaranda trees remaining. In this case, a street in the same suburb was identified and Jacaranda trees were measured to replace the missing trees from this study that were measured in the baseline study.

Table 3.1 shows the streets measured in the baseline study that had less than 20 Jacaranda trees or no Jacaranda trees and the streets used to replace the 20 trees in this study as well as the number of trees measured in each of the streets.

| **Suburb and street from baseline study** | **Street Measured in Baseline study** | **Street measured in this study** | **No. of trees measured per street** |
|---|---|---|---|
| Wingate Park | Delmas | Klipbank | 10 |
| | | Sout | 5 |
| | | Peddie | 3 |
| | | Ketting | 2 |
| Elardus Park | Boeing | Niewenhuyzen | 9 |
| | | Ebenhaezer | 11 |

| | | | |
|---|---|---|---|
| Maroelana | Maroelana and Nuwe Hoop | Maroelana | 10 |
| | | Elandslaagte | 10 |

The exclusion criteria for the study was

- Any trees that were overgrown with the *Hedera helix* (ivy) or had been vandalized were not measured as this would affect the accurate reading of the stem circumference.

### 3.4.3. Data collection method

The researcher made use of a survey to collect the data. According to Mouton (2014) a survey has independent and dependent variables that are defined by the scope of the study. In this study the researcher measured and observed the Jacaranda street trees to determine how much carbon they had sequestrated since they were last measured in the baseline study as well as described additional aspects such as the trees relationship with;

- Pests and diseases
- Infrastructure
- The surface on which the trees are planted and,
- The municipal zoning of the area in which the trees are planted.

The data was collected between July and September of 2017 as well as between May and July of 2019. The data was collected in the following manner:

- The streets listed in Stoffberg (2006) were located using the Google Maps application on a cell phone.
- Upon arrival at the specific street the researcher first determined if the street had *Jacaranda mimosifolia* street trees. If the street had less than 20 trees, the trees in that street were measured and the balance measured in the closest street to the original street in the same suburb. The same was also done if the original street had no remaining Jacaranda trees. It was assumed that all the trees in one suburb were planted at the same time.
- The GPS coordinates were recorded at the first and last tree measured to allow for future investigation.
- The researcher measured the stem circumference at ground level (5cm above the ground) and at breast height (1.37m above the ground) with a tape measure.

- If a tree had multi stems, each stem was measured.
- To determine the health of the tree, the researcher observed the tree canopy for any dying leaves or broken branches (Bond, 2010).
- The researcher observed the tree for any signs of root rot caused by the Garnoderma fungus that attacks and damages the tree cellulose eventually killing the tree (Hennessy & Daly, 2017). An infected tree is identified by the presence of fruiting bodies at the base of the tree (Hennessy & Daly, 2017).
- The researcher also observed the tree for pests such as termites and ants and observed for the presence of the Hedera species (Bond, 2010).
- The researcher also determined the tree's relationship with infrastructure such as streetlights, traffic lights, electric power lines, paving and walls (Most and Weissman, 2012).
- The researcher recorded the surface on which the trees were growing (Mullaney, Lucke & Trueman, 2015).
- The researcher also listed the municipal zoning of the area in which the trees are growing in (Johnston & Hirons, 2014)

Data is presented in multiple formats (i.e., tables, maps, graphs) for ease of evaluation, comparison and for the anticipated use by city officials in urban forest management.

### 3.4.4. Data analysis

Data was captured and analysed in Microsoft ® Excel. For each suburb, the mean and standard deviation were recorded. Data was collected in 2017 and 2019. The goal was to make the data set from 2017 and 2019 to reflect values for 15 years after the baseline study in 2004. A presentation of the data 15 years after the initial study addresses issues of environmental concern such as the growth rate of the trees since the initial study, the amount of carbon sequestrated by the trees as the urban population in the area grows and their energy supply needs increase, how the changing temperature and changing rainfall patterns with regards to global climate change have affected the trees as well as how the spread of diseases and pests as the world becomes more connected affects the trees growth and health. To combine the data, the Annual Growth Rate (AGR) formula was used. The formula is determined as a function for time (Stoffberg, van Rooyen, Groeneveld and van der Linde, 2016). Through the formula, data from Stoffberg (2006), collected in 2004, was compared to the data in this study collected in 2017 and 2019 (See Table 3.2).

The formula reads as follows:

$$\text{AGR} = \frac{\text{a} - \text{b}}{t}$$

- AGR is the Annual Growth Rate (Stoffberg et al, 2016).
- ‘’a’’ is the largest stem diameter (mm). For the data collected in 2017, the 2017 data was the largest stem diameter (Stoffberg et al, 2016).
- ‘’b’’ is the smallest stem diameter (mm). For the data collected in 2017, the data collected in the baseline study in 2004 was the smallest stem diameter (Stoffberg et al, 2016).
- “t” is the time period between the reading years (Stoffberg et al, 2016). For the data collected in 2017 the time period was 13 years (2017 – 2004).
- The formula was then repeated twice in order to obtain values for 2019 (15 years after the initial data collection was done). This process was applied to the mean DBH and mean DGL for each suburb measured in the study.

The data reflected in Table 3.2 only presents information of the 44 suburbs measured in 2017 and then adjusted to reflect numbers for 2019. The data collected in 2019 (28 suburbs) is not reflected in the table as none of those numbers needed to be adjusted.

Table 3.2 Shows the mean Stem Circumference at Breast Height for the suburbs measured in 2017, the corresponding data from 2004, the harmonized data for 2019 and the mean stem circumference average per annum in cm.

| | Suburb | Stem Circumference at Breast Height (mm) | | | | Stem Circumference at Ground Level (mm) | | | Standard Deviation | | Mean Stem Circumference per Annum in cm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2004** | **2017** | **2018** | **2019** | **2017** | **2018** | **2019** | **2018** | **2019** | **2019** |
| 1. | Alphen Park | 913 | 1222 | 1245 | 1269 | 1348 | 1371 | 1395 | 468 | 491 | 3.2 |
| 2. | Arcadia | 1302 | 1459 | 1471 | 1483 | 1737 | 1749 | 1761 | 199 | 211. | 3.0 |
| 3. | Brooklyn | 1446 | 1398 | 1401 | 1404 | 1614 | 1617 | 1620 | 293 | 296 | 1.1 |
| 4. | Claremont | 1644 | 1949 | 1972 | 1995 | 2129 | 2152 | 2175 | 638 | 661 | 3.5 |
| 5. | Clydesdale | 1216 | 1510 | 1532 | 1555 | 1749 | 1771 | 1794 | 508 | 530 | 3.8 |
| 6. | Colbyn | 1616 | 1944 | 1969 | 1994 | 2214 | 2239 | 2264 | 275 | 300 | 4.3 |
| 7. | Constantia Park | 848 | 1010 | 1022 | 1034 | 1246 | 1258 | 1270 | 205 | 217 | 2.8 |
| 8. | Danville | 1129 | 1488 | 1515 | 1543 | 1728 | 1755 | 1783 | 365 | 392 | 4.3 |
| 9. | Eastwood | 1098 | 1016 | 1022 | 1027 | 1154 | 1160 | 1165 | 318 | 323 | 0.4 |
| 10. | Eloffsdal | 1403 | 1359 | 1362 | 1365 | 1597 | 1600 | 1603 | 272 | 274 | 1.3 |
| 11. | Erasmuskloof | 390 | 1223 | 1287 | 1351 | 1252 | 1316 | 1380 | 410 | 474 | 6.6 |
| 12. | Faerie Glen | 522 | 1273 | 1330 | 1388 | 1421 | 1478 | 1536 | 394 | 451 | 6.7 |
| 13. | Garsfontein | 818 | 1209 | 1239 | 1269 | 1293 | 1323 | 1353 | 629 | 659 | 3.5 |
| 14. | Hatfield | 1332 | 1485 | 1496 | 1508 | 1704 | 1715 | 1727 | 236 | 247 | 2.6 |
| 15. | Hestea Park | 278 | 2091 | 2230 | 2369 | 2017 | 2156 | 2295 | 1097 | 1236 | 13.4 |
| 16. | Hillcrest | 1027 | 1159 | 1169 | 1179 | 1432 | 1442 | 1452 | 331 | 341 | 2.8 |
| 17. | Jan Niemand Park | 669 | 1210 | 1251 | 1293 | 1260 | 1301 | 1343 | 387 | 428 | 4.4 |
| 18. | Kilner Park | 810 | 1209 | 1239 | 1270 | 1375 | 1405 | 1436 | 344 | 374 | 4.1 |
| 19. | Kwaggasrand | 1286 | 1572 | 1594 | 1616 | 1824 | 1846 | 1868 | 328 | 350 | 3.8 |
| 20. | Lisdogan Park | 1331 | 1485 | 1496 | 1508 | 1542 | 1553 | 1565 | 569 | 580 | 1.5 |
| 21. | Lukasrand | 1089 | 1176 | 1182 | 1189 | 1418 | 1424 | 1431 | 227 | 233 | 2.2 |
| 22. | Lynwood Glen | 1108 | 1237 | 1246 | 1256 | 1421 | 1430 | 1440 | 269 | 278 | 2.2 |

| | Suburb | Stem Circumference at Breast Height | | | | Stem Circumference at Ground Level | | | Standard Deviation | | Mean Stem Circumference per Annum |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2004** | **2017** | **2018** | **2019** | **2017** | **2018** | **2019** | **2018** | **2019** | **2019 (cm)** |
| 23. | Lynwood Ridge | 626 | 1208 | 1252 | 1297 | 1294 | 1338 | 1383 | 496 | 540 | 5.0 |
| 24. | Menlo Park | 1400 | 1321 | 1327 | 1332 | 1528 | 1534 | 1539 | 445 | 450 | 0.9 |
| 24. | Meyers Park | 1021 | 869 | 880 | 890 | 942 | 953 | 963 | 345 | 355 | 0.3 |
| 26. | Montana | 522 | 1368 | 1433 | 1498 | 1352 | 1417 | 1482 | 291 | 356 | 6.4 |
| 26. | Mucklenuek | 1467 | 1608 | 1618 | 1629 | 1893 | 1903 | 1914 | 272 | 282 | 2.9 |
| 27. | Pretoria Central | 1420 | 1307 | 1315 | 1323 | 1618 | 1626 | 1634 | 371 | 378 | 1.4 |
| 28. | Pretoria Gardens | 1471 | 1382 | 1388 | 1394 | 1592 | 1598 | 1604 | 322 | 327 | 0.8 |
| 28. | Proclamation Hill | 1345 | 1430 | 1436 | 1443 | 1727 | 1733 | 1740 | 390 | 396 | 2.6 |
| 29. | Queenswood | 1039 | 1096 | 1100 | 1104 | 1200 | 1204 | 1208 | 364 | 368 | 1.1 |
| 30. | Rietondale | 1400 | 2020 | 2067 | 2115 | 2280 | 2327 | 2375 | 380 | 427 | 6.5 |
| 31. | Riviera | 1497 | 2149 | 2199 | 2249 | 2311 | 2361 | 2411 | 305 | 355 | 6.0 |
| 32. | Salvokop | 1392 | 1371 | 1372 | 1374 | 1426 | 1427 | 1429 | 745 | 746 | 0.2 |
| 33. | Silverton | 1233 | 1506 | 1527 | 1548 | 1830 | 1851 | 1872 | 295 | 316 | 4.2 |
| 34. | Sinoville | 1532 | 2111 | 2155 | 2200. | 2127 | 2171 | 2216 | 611 | 655 | 4.5 |
| 35. | Sunnyside | 1383 | 1555 | 1568 | 1581 | 1804 | 1817 | 1830 | 313 | 326 | 2.9 |
| 36. | Valhalla | 1256 | 1654 | 1684 | 1715 | 1678 | 1708 | 1739 | 442 | 472 | 3.2 |
| 37. | Villiera | 1410 | 1500 | 1506 | 1513 | 1884 | 1890 | 1897 | 300 | 306 | 3.2 |
| 38. | Waterkloof | 1538 | 1708 | 1721 | 1734 | 1713 | 1726 | 1739 | 690 | 703 | 1.3 |
| 39. | Waterkloof Glen | 805 | 1010 | 1025 | 1041 | 1246 | 1261 | 1277 | 205 | 220 | 3.1 |
| 40. | Waterkloof Park | 824 | 1420 | 1465 | 1511 | 1366 | 1411 | 1457 | 627 | 672 | 4.2 |
| 41. | Waterkloof Ridge | 1102 | 1506 | 1537 | 1568 | 1486 | 1517 | 1548 | 511 | 542 | 2.9 |
| 42. | Wes Park | 1159 | 1521 | 1548 | 1576 | 1771 | 1798 | 1826 | 216 | 243 | 4.4 |
| 43. | Watloo | 1063 | 1634 | 1677 | 1721 | 1594 | 1637 | 1681 | 421 | 464 | 4.1 |
| 44. | Wonderboom South | 1552 | 1813 | 1833 | 1853 | 2095 | 2115 | 2135 | 366 | 386 | 3.8 |

#### 3.4.4.1. Multi stem Calculations

McPherson, van Doorn and Peper (2016) provide a formula for calculations that involve trees with multiple stems. The formula reads as follow:

$$DRC = SQRT\ [\ SUM\ (stem\ diameter^{2})]$$

where *DRC* stands for the Diameter at Root Collar and *SQRT* is the "Square Root"

This study used this formula for trees with multiple stems. The stem circumference values were first converted into diameter and then applied to the DRC formula.

#### 3.4.4.2. Carbon Calculations

In this section the methodology used to calculate carbon storage and sequestration is discussed.

The equations below were used in this study as presented in the baseline study by Stoffberg (2006) to calculate the mean and total carbon (See Table 4.5 to Table 4.7). They are repeated for ease of reading and referral.

The first equation from Pillsbury, Reimer and Thompson (1998) was used to calculate the volume of the tree. Two formulas are given namely the local volume equation, which uses dbh to estimate the tree volume, and the standard volume equation which uses both dbh and height to estimate the tree volume (Pillsbury et al, 1998) This study used the local volume equation as only the dbh was measured. Pillsbury et al (1998) provides the following formula to calculate the tree volume of the *Jacaranda mimosifolia* tree.

$$V\ (cf) = 0.036147\ (dbh)^{2.486248} \qquad 1.$$

where *V (cf)* is the volume of the aboveground woody parts (excluding leaf volumes) of the tree in cubic feet and dbh is the stem diameter at breast height in inches (Pillsbury et al, 1998).

Equation 1 was then converted into metric units. It reads as follows:

$$V\ (m)^{3} = 3.29118 * 10^{-7}\ (dbh\ (mm))^{2.486248} \qquad 2.$$

where *V (m)* $^3$ is the volume aboveground woody parts in cubic meters and dbh (mm) is the stem diameter in millimeters at breast height. The stem circumference was converted into diameters in order to apply the measurements to equation 2. After the volume of each tree was calculated its biomass was calculated. The formula reads as follows:

$$Biomass = density * V\,(m)^3 \qquad 3.$$

where Biomass is calculated in kilograms (kg) and *density* is a given value. This study used the density value of 520kg/$m^3$. The value was determined from sampling stem wood derived from a *Jacaranda mimosifolia* tree that grew on the University of Pretoria campus. The wood was oven dried to a constant mass and the density was calculated.

According to Mcpherson, Nowak and Rowntree (1994), Mcpherson and Simpson (1999) and IPCC (2003), fifty percent of the aboveground biomass is allocated to carbon. This value was then converted into metric tonnes. The mean aboveground carbon per suburb as well as the standard deviation was calculated for each suburb.

The following formula is used to calculate the standard error for the aboveground carbon per suburb. The formula reads as follows:

$$\mathrm{SE} = \frac{\mathrm{SD}}{\sqrt{(\mathrm{n})}} \qquad 4.$$

where *SE* is the standard error, *SD* is the standard deviation. SD is the measure the variability of individual trees within the suburb. The standard error *(SE)* is a measure of the accuracy of the estimated mean for the suburb. A correction factor was applied to the standard error. It was derived from the following equation:

$$c = \sqrt{\frac{\mathrm{W_i - n}}{\mathrm{W_i - 1}}} \qquad 5.$$

where *c* is the correction factor, *Wi* is the total number of trees in the suburb and *n* is the sample size in the particular suburb. The correction factor was applied to the *SE* as follows:

$$\mathrm{SE(c) = SE*c} \qquad 6.$$

where SE(c) is the corrected standard error. The mean quantity of aboveground carbon per Jacaranda tree in Tshwane can be calculated as follows:

$$X \quad \frac{\sum(W_i * X_i)}{\sum W_i} \qquad 7.$$

where $X$ is the mean quantity of aboveground carbon per Jacaranda tree in Tshwane. $W_i$ is the total number of trees in each suburb and $X_i$ is the mean aboveground carbon per tree for each suburb. The total quantity of aboveground carbon that has been sequestrated by all Jacaranda trees in Tshwane ($C_{agt}$) can be calculated as follows:

$$C_{agt} = X*N \qquad 8.$$

where $N$ is the total number of Jacaranda trees in Tshwane. The carbon standard error per tree ($SE_{pertree}$) was calculated as follows:

$$SE_{pertree} = \sqrt{\frac{\sum W_i^2 \, SE\,(c)_i^2}{(\sum W_i)^2}} \qquad 9.$$

From the above equation the standard error for the above ground carbon of the total quantity of trees was calculated as follows:

$$SE_{total} = N * SE_{pertree} \qquad 10.$$

where $SE$total is the standard error of the aboveground carbon for the total quantity of trees. The percentage error *(%Err)* is calculated as follows:

$$\%Err = \frac{SE_{total}}{C_{agt}} * 100 * 2 \qquad 11.$$

To determine the aboveground and belowground biomass of the Jacaranda root/shoot ratio of 22:78 was used and equations (4) to (11) were repeated to determine the total carbon quantities that include root carbon. The percentage of carbon of the root was also taken as 50% of the total biomass (McPherson et al, 1994; McPherson & Simpson,1994; and IPCC, 2003). The Carbon Dioxide equivalent ($CO_2$eq) was calculated by multiplying the atomic mass of carbon by 3.67 (McPherson & Simpson, 1999) (Table 4.8 to Table 4.10). Once the $CO_2$eq values were determined, the baseline study used a hypothetical market price of one tonne of $CO_2$eq is equal to US$10 to calculate the dollar value. The baseline study then determined the Rand value of $CO_2$eq by using the US$1 is equal to R6.59 conversion based on the exchange rate at the time. In the current study the Rand value of the $CO_2$eq was calculated using the 1 tonne of $CO_2$eq being equal to R120 conversion as stipulated in the Carbon Tax Bill (2010) provided by the South African National Treasury. The US dollar values were calculated by using a monetary related value of US$1 is equal to R15 exchange rate applicable at the time of calculation (businesstech.co.za, 2018). To calculate this value the Rand value was divided by 15.

## 3.5. Reliability and validity

### 3.5.1. Validity

The validity of an instrument determines the extent to which it reflects the abstract construct being examined. Validity is divided into three main types namely construct validity, predictive validity and face validity (Gray, Grove and Sutherland 2017). In this study the researcher used an existing data collection instrument whose validity was already established in the baseline study and is in common usage in the urban forestry industry (Stoffberg, 2006).

### 3.5.2. Reliability

Reliability of an instrument refers to the consistency of the measurements obtained in the use of the particular instrument and indicates the extent of random error in the measurement method (Gray, Grove & Sutherland, 2017). Using the same method used to collect data in the baseline study, reliability was maintained.

### 3.5.3. Study Limitations

A limitation of the study was that some of the trees measured in the baseline study in 2004 were no longer available for measurement in this study. Trees in other streets in this study were then measured to account for this limitation. Similarly, to the baseline study, it was assumed that all trees in one suburb were planted at the same time. The baseline study measure trees along Simon Vermooten in Samcor park, however, this study found that all the Jacaranda tree in that street had since been replaced with other trees of a different species. No other streets were found to replace Simon Vermooten and therefore no trees were measured in this suburb in this study. Some trees that were measured in the baseline study were also found to be heavily infested with ivy, particularly at the ground level. A number of trees in the CBD area of the City of Tshwane were vandalized and could therefore not be measured. It was also found that some of the trees measured in the baseline study were now incorporated into private gardens and could not be measured in this study. Other streets in the same suburbs were identified and sampled to counter this limitation. Initially data collection was scheduled to take place in a one-year period but due to unforeseen circumstances, this process took place over two years.

### 3.6 Summary

The focus of this chapter was the description of the research design and method applied in this study. The researcher described the population, sample and sampling method, data collection and analysis methods and how validity and reliability was established. The chapter also gave a detailed explanation of how the data was collected and the formulae used to calculate the carbon and carbon dioxide equivalent values and the corresponding Rand and Dollar values. The findings of the study are described in chapter 4.

# CHAPTER 4: RESULTS AND DATA ANALYSIS

## 4.1. Introduction

This chapter focuses on the results of the data collected for this study. The chapter also compares the data from when the study was first conducted in the baseline study to the data collected for this study highlighting where the highest and lowest values occurred in the 72 suburbs measured.

A total number of 1540 of Jacaranda street trees were measured in 72 suburbs in the City of Tshwane between May and October of 2017 and between May and June of 2019. The data was then synchronized and adjusted using the Annual Growth Formula (AGR) to reflect values for 2019 (See Methodology above).

This chapter also provides a description of the biophysical and physical conditions in which in the trees are growing looking at the pests and diseases that may be affecting the trees, the municipal zoning of the suburbs in which the trees are growing, the ground on which the trees are growing as well as the trees relationship with built infrastructure.

## 4.2. Results

The calculations in the baseline study were based on a total number of 33 630 Jacaranda street trees. Through personal communication with Mr. B Dry form the City of Tshwane Municipality (24 July 2019), it was confirmed that no other census of the Jacaranda street tree population was done post the baseline study. Mr. B Dry also confirmed that the Jacaranda street tree population was stable, and its numbers were maintained. No new trees were planted. Only the replacement of existing trees took place. Therefore, the same total values of trees per suburb were used in the calculations in this study.

Table 4.1 lists all the suburbs in which Jacaranda street trees were measured in the baseline study and similarly in this study. The table provides the geographical location at the first and last tree measured along the relevant streets. No trees were measured along Simon Vermooten in Samcor Park as the trees have since been replaced with other trees of a different species. Figure 4.1 is a map of the number of trees in each suburb based on the same numbers used in the baseline study. Suburbs with more than 1000 trees include Pretoria Central, Brooklyn, Arcadia, Sunnyside, Waterkloof Ridge, Waterkloof, Villiera and Rietfontein respectively. These suburbs are represented with the darkest colour on the map.

Table 4.1 shows the suburb name and the GPS co-ordinates for the first and last trees in each street for the Jacaranda street trees. In some suburbs more than one street was measured (Please see Methodology).

| Suburb | Street name | Start GPS South | | | Start GPS East | | | End GPS South | | | End GPS East | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **degree** | **minute** | **second** | **degree** | **minute** | **second** | **degree** | **minute** | **second** | **degree** | **minute** | **second** |
| 1. Alphen Park | Dely | 25 | 47 | 04.7 | 28 | 15 | 37.5 | 25 | 47 | 12.6 | 28 | 15 | 42.3 |
| 2. Annlin | Sefako Magatho | 25 | 40 | 37.8 | 28 | 11 | 49.6 | 25 | 40 | 41.7 | 28 | 12 | 06.8 |
| 3. Arcadia | Schoeman | 25 | 44 | 49.9 | 28 | 13 | 03.7 | 25 | 44 | 49.2 | 28 | 13 | 16.0 |
| 4. Asiatic Bazaar | Jerusalem | 25 | 44 | 28.9 | 28 | 10 | 31.6 | 25 | 44 | 21.8 | 28 | 10 | 30.9 |
| 5.Ashlea Gardens | Matroosberg | 25 | 47 | 05.1 | 28 | 16 | 00.4 | 25 | 47 | 08.4 | 28 | 16 | 00.8 |
| 6. Attridgeville | Maunde | 25 | 46 | 51.9 | 28 | 3 | 08.8 | 25 | 46 | 49.8 | 28 | 3 | 19.7 |
| 7. Brooklyn | Mackenzie | 25 | 45 | 52.2 | 28 | 14 | 17.9 | 25 | 45 | 54.7 | 28 | 14 | 29.0 |
| | Brooks | 25 | 45 | 32.7 | 28 | 14 | 01.7 | 25 | 45 | 34.6 | 28 | 14 | 13.9 |
| 8. Claremont | Diamond | 25 | 43 | 31.1 | 28 | 07 | 56.7 | 25 | 43 | 26.3 | 28 | 07 | 57.7 |
| 9. Clydesdale | Kirkness | 25 | 45 | 02.3 | 28 | 13 | 20.2 | 25 | 45 | 19.2 | 28 | 13 | 17.9 |
| 10. Colbyn | Amos | 25 | 44 | 21.5 | 28 | 14 | 14.6 | 25 | 44 | 21.9 | 28 | 14 | 27.9 |
| 11. Constantia Park | Anton van Wouw | 25 | 47 | 57.1 | 28 | 17 | 06.0 | 25 | 48 | 04.7 | 28 | 17 | 12.8 |
| 12. Danville | Wrentmore | 25 | 44 | 07.1 | 28 | 7 | 59.5 | 25 | 44 | 07.8 | 28 | 8 | 03.8 |
| 13. Eastwood | Government | 25 | 44 | 23.6 | 28 | 13 | 00.8 | 25 | 44 | 24.6 | 28 | 13 | 05.0 |
| 14. Eerterust | Hans Coverdale North | 25 | 42 | 00.0 | 28 | 18 | 33.7 | 25 | 42 | 03.2 | 28 | 18 | 15.3 |
| 15. Elardus Park | Niewenhuyzen | 25 | 49 | 37.0 | 28 | 15 | 10.0 | 25 | 49 | 38.5 | 28 | 15 | 08.8 |
| | Ebenhaerzer | 25 | 49 | 38.7 | 28 | 15 | 08.9 | 25 | 49 | 39.5 | 28 | 15 | 10.7 |
| 16. Eloffsdal | Franzina | 25 | 42 | 45.7 | 28 | 11 | 07.4 | 25 | 42 | 44.6 | 28 | 10 | 57.4 |
| 17. Erasmusrand | Louis | 25 | 48 | 53.1 | 28 | 16 | 07.3 | 25 | 48 | 42.9 | 28 | 16 | 09.5 |
| 18. Erasmuskloof | Rigel | 25 | 48 | 27.7 | 28 | 14 | 54.6 | 25 | 48 | 31.0 | 28 | 15 | 17.6 |
| 19. Faerie Glen | Olympus | 25 | 47 | 43.7 | 28 | 19 | 49.0 | 25 | 47 | 36.3 | 28 | 19 | 49.4 |
| 20. Garsfontein | Serene | 25 | 47 | 44.9 | 28 | 17 | 53.2 | 25 | 47 | 47.0 | 28 | 17 | 34.1 |
| 21. Hatfield | Prospect | 25 | 45 | 06.1 | 28 | 14 | 24.0 | 25 | 45 | 06.8 | 28 | 14 | 13.9 |

| Suburb | Street name | Start GPS South | | | Start GPS East | | | End GPS South | | | End GPS East | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | degree | minute | second | degree | minute | second | degree | minute | second | degree | minute | second |
| 22. Hazelwood | Dely | 25 | 46 | 40.0 | 28 | 15 | 20.8 | 25 | 46 | 55.0 | 28 | 15 | 30.0 |
| 23. Hestea Park | Daan de Wet Nel Dr | 25 | 38 | 54.2 | 28 | 7 | 35.0 | 25 | 38 | 56.0 | 28 | 7 | 43.0 |
| 24. Hillcrest | Duxbury | 25 | 45 | 20.2 | 28 | 14 | 20.8 | 25 | 45 | 18.7 | 28 | 14 | 13.9 |
| 25. an Niemand Park | Uil | 25 | 42 | 10.8 | 28 | 17 | 33.4 | 25 | 42 | 07.9 | 28 | 17 | 20.8 |
| 26. Kilner Park | CR. Swart | 25 | 43 | 55.2 | 28 | 15 | 31.0 | 25 | 43 | 42.6 | 28 | 15 | 31.0 |
| 27. Kwaggasrand | Reier | 25 | 45 | 43.9 | 28 | 7 | 05.9 | 25 | 45 | 41.8 | 28 | 7 | 01.6 |
| 28. La Montagne | Catharina | 25 | 44 | 44.0 | 28 | 18 | 45.1 | 25 | 44 | 44.9 | 28 | 19 | 00.7 |
| 29. Laudium | Emerald | 25 | 47 | 07.0 | 28 | 6 | 29.3 | 25 | 47 | 07.9 | 28 | 6 | 17.9 |
| 30. Lisdogan Park | Government | 25 | 44 | 25.4 | 28 | 13 | 29.4 | 25 | 44 | 26.7 | 28 | 13 | 26.5 |
| 31. Lukasrand | Sibelius | 25 | 45 | 57.2 | 28 | 12 | 45.7 | 25 | 45 | 56.9 | 28 | 12 | 55.1 |
| 32. Lynwood | Elizabeth Grove South | 25 | 45 | 34.5 | 28 | 15 | 48.1 | 25 | 45 | 29.2 | 28 | 15 | 48.1 |
| 33. Lynwood Glen | Glenwood | 25 | 46 | 05.2 | 28 | 16 | 45.1 | 25 | 46 | 16.0 | 28 | 16 | 45.8 |
| 34. Lynwood Ridge | Freesia | 25 | 43 | 54.8 | 28 | 17 | 24.0 | 25 | 46 | 00.5 | 28 | 17 | 54.6 |
| 35. Mamelodi | Tsamaya Avenue | 25 | 42 | 36.0 | 28 | 22 | 56.3 | 25 | 42 | 31.0 | 28 | 23 | 04.8 |
| 36. Maroelana | Maroelana | 25 | 46 | 44.2 | 28 | 15 | 36.0 | 25 | 46 | 46.5 | 28 | 15 | 35.2 |
| 37. Mayville | Mansfield | 25 | 42 | 45.9 | 28 | 11 | 09.4 | 25 | 42 | 41.1 | 28 | 11 | 09.9 |
| 38. Menlo Park | Brooklyn | 25 | 45 | 38.0 | 28 | 14 | 42.5 | 25 | 45 | 59.8 | 28 | 14 | 56.8 |
| 39. Meyers Park | Pretoria | 25 | 44 | 10.7 | 28 | 19 | 22.1 | 25 | 44 | 13.2 | 28 | 19 | 35.4 |
| 40. Montana | Sefako Magatho | 25 | 40 | 43.3 | 28 | 12 | 19.1 | 25 | 40 | 46.9 | 28 | 12 | 40.0 |
| 41. Moreleta Park | Rubenstein | 25 | 49 | 07.8 | 28 | 16 | 55.9 | 25 | 49 | 07.1 | 28 | 17 | 03.4 |
| 42. Mountain View | Daniel | 25 | 41 | 56.0 | 28 | 9 | 23.1 | 25 | 41 | 51.5 | 28 | 9 | 23.7 |
| 43. Muckleneuk | Bourke | 25 | 45 | 33.8 | 28 | 12 | 24.3 | 25 | 45 | 40.7 | 28 | 12 | 23.4 |
| 44. Newlands | Dely | 25 | 47 | 32.0 | 28 | 15 | 53.5 | 25 | 47 | 36.1 | 28 | 15 | 57.6 |
| 45. Nieuw Muckleneuk | Dey | 25 | 46 | 17.0 | 28 | 13 | 49.5 | 25 | 46 | 14.1 | 28 | 13 | 48.4 |
| 46. Philip Nel Pak | Staatsartellerie | 25 | 44 | 20.3 | 28 | 9 | 33.1 | 25 | 44 | 22.8 | 28 | 9 | 14.2 |
| 47. Pretoria Central | Bloed | 25 | 44 | 49.2 | 28 | 11 | 06.7 | 25 | 44 | 28.0 | 28 | 11 | 23.3 |

| Suburb | Street name | Start GPS South | | | Start GPS East | | | End GPS South | | | End GPS East | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | degree | minute | second | degree | minute | second | degree | minute | second | degree | minute | second |
| | Visagie | 25 | 45 | 09.4 | 28 | 11 | 19.7 | 25 | 45 | 06.8 | 28 | 11 | 52.8 |
| 48. Pretoria Gardens | Bornman | 25 | 43 | 35.4 | 28 | 8 | 33.0 | 25 | 43 | 25.0 | 28 | 8 | 34.4 |
| 49. Pretoria Industrial | Staal | 25 | 45 | 51.4 | 28 | 7 | 51.0 | 25 | 45 | 45.9 | 28 | 7 | 57.9 |
| 50. Pretoria North | Brits | 25 | 40 | 47.7 | 28 | 9 | 57.6 | 25 | 40 | 48.4 | 28 | 10 | 07.6 |
| 51. Pretoria West | Servaas | 25 | 45 | 06.5 | 28 | 9 | 18.7 | 25 | 45 | 06.1 | 28 | 9 | 26.6 |
| 52. Proclamation Hill | Acacia | 25 | 45 | 05.8 | 28 | 8 | 20.0 | 25 | 45 | 06.5 | 28 | 8 | 14.3 |
| 53. Queenswood | Soutpansberg | 25 | 44 | 02.0 | 28 | 13 | 23.9 | 25 | 44 | 01.7 | 28 | 13 | 16.3 |
| 54. Rietfontein | 19th Avenue | 25 | 42 | 43.0 | 28 | 13 | 09.4 | 25 | 42 | 36.3 | 28 | 13 | 08.2 |
| 55. Rietondale | Nuffield | 25 | 43 | 39.7 | 28 | 13 | 09.8 | 25 | 43 | 45.1 | 28 | 13 | 09.8 |
| 56. Riviera | Annie Botha | 25 | 43 | 57.7 | 28 | 12 | 53.3 | 25 | 43 | 58.1 | 28 | 12 | 45.0 |
| 57. Samcor Park | Simon Vermooten | **Jacaranda Trees transplanted and other trees of a different species planted in their place** | | | | | | | | | | | |
| 58. Saulsville | Masopha | 25 | 46 | 10.0 | 28 | 3 | 20.6 | 25 | 46 | 15.0 | 28 | 3 | 15.7 |
| | Makhaza | 25 | 46 | 42.0 | 28 | 3 | 04.9 | 25 | 46 | 34.1 | 28 | 2 | 55.7 |
| 59. Salvokop | Skietport | 25 | 45 | 35.3 | 28 | 11 | 11.8 | 25 | 45 | 35.3 | 28 | 11 | 07.8 |
| 60. Silverton | Fakkel | 25 | 43 | 54.8 | 28 | 17 | 46.7 | 25 | 44 | 10.7 | 28 | 17 | 45.2 |
| 61. Sinoville | Sefako Magatho | 25 | 40 | 43.0 | 28 | 14 | 32.3 | 25 | 40 | 51.6 | 28 | 14 | 00.2 |
| 62. Sunnyside | Bourke | 25 | 45 | 25.6 | 28 | 12 | 28.1 | 25 | 45 | 40.7 | 28 | 12 | 23.4 |
| | Jorrison | 25 | 45 | 25.3 | 28 | 12 | 38.6 | 25 | 45 | 27.2 | 28 | 12 | 52.7 |
| 63. Trevena | Meintjie | 25 | 44 | 55.0 | 28 | 12 | 11.1 | 25 | 45 | 07.4 | 28 | 12 | 02.2 |
| 64. Valhalla | Fjord | 25 | 47 | 46.3 | 28 | 9 | 32.8 | 25 | 47 | 53.5 | 28 | 9 | 28.1 |
| 65. Villiera | Pierneef | 25 | 43 | 19.2 | 28 | 14 | 05.6 | 25 | 43 | 18.8 | 28 | 14 | 16.1 |
| 66. Waterkloof | Milner (both side) | 25 | 46 | 43.0 | 28 | 14 | 16.4 | 25 | 46 | 44.4 | 28 | 14 | 00.2 |
| | Milner (one sides) | 25 | 46 | 36.5 | 28 | 15 | 04.7 | 25 | 46 | 38.6 | 28 | 14 | 49.2 |
| 67.Waterkloof Glen | Anton van Wouw | 25 | 47 | 56.0 | 28 | 17 | 04.9 | 25 | 47 | 50.6 | 28 | 17 | 00.4 |
| 68. Waterkloof Park | Drakensberg | 25 | 47 | 21.8 | 28 | 15 | 35.3 | 25 | 47 | 05.3 | 28 | 15 | 28.4 |
| 69. Waterkloof Ridge | Delphinus | 25 | 47 | 09.4 | 28 | 14 | 55.1 | 25 | 47 | 17.3 | 28 | 14 | 40.5 |

| Suburb | Street name | Start GPS South | | | Start GPS East | | | End GPS South | | | End GPS East | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **degree** | **minute** | **second** | **degree** | **minute** | **second** | **degree** | **minute** | **second** | **degree** | **minute** | **second** |
| 70.Wes Park | Iscor | 25 | 45 | 08.3 | 28 | 7 | 50.3 | 25 | 45 | 18.2 | 28 | 7 | 41.7 |
| 71. Watloo | Mundt | 25 | 43 | 21.1 | 28 | 19 | 45.3 | 25 | 43 | 19.9 | 28 | 19 | 37.9 |
| 72. Wingate Park | Klipbank | 25 | 49 | 30.9 | 28 | 16 | 07.2 | 25 | 49 | 30.6 | 28 | 16 | 05.2 |
| | Sout | 25 | 49 | 21.5 | 28 | 16 | 37.5 | 25 | 49 | 22.3 | 28 | 16 | 37.3 |
| | Peddie | 25 | 49 | 24.1 | 28 | 16 | 20.4 | 25 | 49 | 22.1 | 28 | 16 | 21.2 |
| | Delmas | 25 | 50 | 09.0 | 28 | 16 | 08.1 | 25 | 50 | 09.6 | 28 | 16 | 08.5 |
| 73. Wonderboom South | De Beer | 25 | 44 | 55.7 | 28 | 12 | 00.0 | 25 | 41 | 53.9 | 28 | 12 | 11.2 |

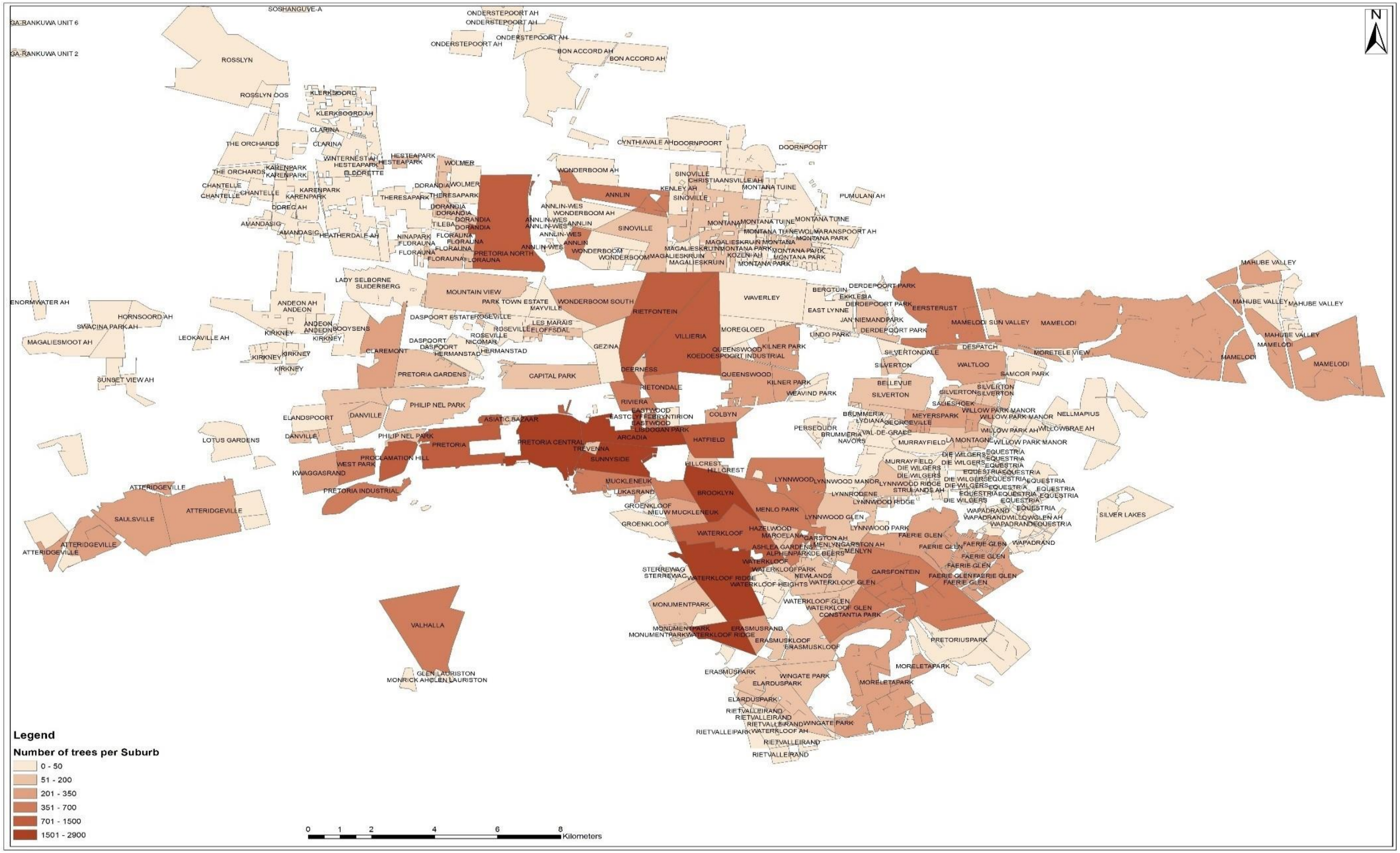


Figure 4.1: Map showing the number of Jacaranda street trees per suburb.

### 4.2.1. Mean Stem Circumference and Mean Stem Diameter

Table 4.2 shows the Mean Stem Circumference and the Mean Stem Diameter measured at Breast Height in the baseline study in 2004 and the Mean Stem Circumference and Mean Stem Diameter measured at Breast Height and Ground Level in this study (2019). The table also provides the standard deviation for these measurements per suburb.

Table 4.3 shows the mean stem circumference and the mean stem diameter measured at breast height in the baseline study in 2004 and the mean stem circumference and mean stem diameter measured at breast height and ground level in this study (2019). The table also provides the standard deviation for these measurements per suburb. This table lists the mean stem circumference in descending order for the baseline study. In the baseline study suburbs with the highest mean stem circumferences at breast height were Asiatic Bazaar, Laudium, Claremont and Colbyn with mean stem circumference at breast height values of 1687mm, 1671mm, 1644mm and 1616 mm, respectively. The corresponding mean stem diameter value at breast height were 536mm, 532mm, 524mm and 515mm, respectively. Suburbs with the lowest mean stem circumference values in the baseline study were Elardus Park, Hestea Park, Newlands and Wingate Park with Mean Stem Circumference values of 323mm, 278mm, 213mm and 195mm respectively. The corresponding mean stem diameter values at breast height were 103mm, 89mm, 68mm and 62mm, respectively.

Table 4.4 shows the mean stem circumference and the mean stem diameter at breast height and at ground level in this study in descending order. Suburbs with the highest mean stem circumference values at breast height were Hestea Park. Riviera, Sinoville and Rietondale with mean stem circumference values of 2369mm, 2249mm, 2200mm and 2115mm, respectively. The corresponding mean stem diameter values at breast height were 544mm, 766mm, 699mm and 673mm, respectively. The mean stem circumference at ground level for these suburbs was 2295mm, 2411mm, 2216mm and 2375mm, respectively. The corresponding mean stem diameter at ground level values were 731mm, 768mm, 706mm and 756mm, respectively. Suburbs with the lowest mean stem circumference values at breast height were Eastwood, Erasmusrand, Elardus Park and Meyers Park with mean stem circumference at breast height values of 1027mm, 975mm, 958mm and 890mm, respectively. The corresponding mean stem diameter values at breast height for these suburbs were 327mm, 310mm, 305mm and 252mm, respectively. The mean stem circumference at ground level for these suburbs was 1165mm, 1136mm, 1134mm and 963mm, respectively. The corresponding mean stem diameter at ground level values were 371mm, 439mm, 361mm and 307mm, respectively.

Figure 4.2 shows the mean stem circumference at breast height for each suburb measured in this study. The darker colours are representative of the suburbs with the highest mean stem circumference values.

Figure 4.3 shows the mean stem circumference at ground level for each suburb measured in this study. The darker colours are representative of the suburbs with the highest mean stem circumference values.

Figure 4.4 shows the difference between the mean stem circumference measured at breast height in 2004 and 2019. The suburbs with the lighter colours are representative of the suburbs with the highest mean stem circumference difference at breast height.

Table 4.2 shows the suburb names, the Mean Stem Circumference at Breast Height (BH) and at Ground Level (GL), the Mean Stem Diameter at Breast Height (DBH) and at Ground Level (DGL) as well as the standard deviation (mm) for both Stem Circumference and Diameter in 2004.and 2019 in *alphabetical order*.

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation (Stem Circumference) (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 |
| 1. | Alphen Park | 913 | 1380 | 1395 | 291 | 439 | 444 | 258 | 491 | 454 | 82 | 156 | 144 |
| 2. | Annlin | 1218 | 1681 | 1835 | 388 | 535 | 584 | 417 | 451 | 368 | 133 | 143 | 117 |
| 3. | Arcadia | 1302 | 1483 | 1761 | 415 | 472 | 561 | 199 | 211 | 285 | 63 | 67 | 90 |
| 4. | Asiatic Bazaar | 1687 | 1683 | 2061 | 537 | 536 | 656 | 320 | 451 | 315 | 102 | 143 | 100 |
| 5. | Ashlea Gardens | 1060 | 1365 | 1504 | 338 | 435 | 479 | 389 | 511 | 253 | 124 | 162 | 80 |
| 6. | Atteridgeville | 814 | 1070 | 1254 | 259 | 341 | 399 | 119 | 542 | 331 | 38 | 172 | 105 |
| 7. | Brooklyn | 1446 | 1549 | 1620 | 461 | 493 | 516 | 187 | 387 | 380 | 60 | 123 | 121 |
| 8. | Claremont | 1644 | 1890 | 2175 | 524 | 602 | 693 | 316 | 471 | 490 | 101 | 150 | 156 |
| 9. | Clydesdale | 1216 | 1460 | 1794 | 387 | 465 | 571 | 236 | 331 | 349 | 75 | 105 | 111 |
| 10. | Colbyn | 1616 | 1994 | 2264 | 515 | 635 | 721 | 263 | 300 | 343 | 84 | 95 | 109 |
| 11. | Constantia Park | 848 | 1034 | 1270 | 270 | 329 | 404 | 175 | 217 | 291 | 56 | 69 | 92 |
| 12. | Danville | 1129 | 1543 | 1783 | 360 | 491 | 568 | 254 | 392 | 449 | 81 | 124 | 142 |
| 13. | Eastwood | 1098 | 1027 | 1165 | 350 | 327 | 371 | 288 | 323 | 264 | 92 | 102 | 84 |
| 14. | Eersterust | 1049 | 1767 | 1860 | 334 | 563 | 592 | 257 | 447 | 380 | 82 | 142 | 121 |
| 15. | Elardus Park | 323 | 958 | 1134 | 103 | 305 | 361 | 91 | 241 | 208 | 29 | 76 | 66 |
| 16. | Eloffsdal | 1403 | 1365 | 1603 | 447 | 435 | 511 | 402 | 274 | 317 | 128 | 87 | 100 |
| 17. | Erasmuskloof | 390 | 1102 | 1380 | 246 | 311 | 362 | 162 | 297 | 352 | 52 | 94 | 112 |
| 18. | Erasmusrand | 773 | 975 | 1136 | 124 | 351 | 439 | 204 | 270 | 265 | 65 | 85 | 84 |
| 19. | Faerie Glen | 522 | 1206 | 1536 | 166 | 384 | 489 | 124 | 243 | 296 | 40 | 77 | 94 |
| 20. | Garsfontein | 818 | 1120 | 1353 | 261 | 357 | 431 | 191 | 443 | 466 | 61 | 141 | 148 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation (Stem Circumference) (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BH 2004** | **BH 2019** | **GL 2019** | **DBH 2004** | **DBH 2019** | **DGL 2019** | **BH 2004** | **BH 2019** | **GL 2019** | **DBH 2004** | **DBH 2019** | **DGL 2019** |
| 21. | Hatfield | 1332 | 1508 | 1727 | 424 | 480 | 550 | 171 | 247 | 279 | 54 | 78 | 88 |
| 22. | Hazelwood | 523 | 1286 | 1407 | 167 | 410 | 477 | 347 | 665 | 501 | 111 | 211 | 159 |
| 23. | Hestea Park | 278 | 1708 | 2295 | 89 | 544 | 731 | 85 | 631 | 742 | 27 | 200 | 236 |
| 24. | Hillcrest | 1027 | 1179 | 1452 | 327 | 375 | 462 | 264 | 341 | 423 | 84 | 108 | 134 |
| 25. | Jan Niemand Park | 669 | 1096 | 1343 | 213 | 349 | 428 | 273 | 243 | 276 | 87 | 77 | 87 |
| 26. | Kilner Park | 810 | 1431 | 1436 | 258 | 456 | 457 | 207 | 374 | 347 | 66 | 119 | 110 |
| 27. | Kwaggasrand | 1286 | 1860 | 1868 | 410 | 592 | 595 | 166 | 350 | 327 | 53 | 111 | 104 |
| 28. | La Montagne | 898 | 1385 | 1525 | 286 | 441 | 486 | 310 | 552 | 359 | 99 | 175 | 114 |
| 29. | Laudium | 1671 | 1898 | 2093 | 532 | 604 | 667 | 245 | 583 | 463 | 78 | 185 | 147 |
| 30. | Lisdogan Park | 1331 | 1550 | 1565 | 424 | 493 | 498 | 338 | 580 | 434 | 108 | 184 | 138 |
| 31. | Lukasrand | 1089 | 1189 | 1431 | 347 | 379 | 456 | 252 | 233 | 273 | 80 | 74 | 86 |
| 32. | Lynnwood | 1395 | 1602 | 1645 | 444 | 510 | 524 | 486 | 1052 | 547 | 155 | 335 | 174 |
| 33. | Lynnwood Glen | 1108 | 1256 | 1440 | 353 | 400 | 459 | 187 | 278 | 324 | 60 | 88 | 103 |
| 34. | Lynnwood Ridge | 626 | 1369 | 1383 | 199 | 436 | 440 | 156 | 540 | 354 | 50 | 171 | 112 |
| 35. | Mamelodi | 736 | 1336 | 1410 | 234 | 426 | 449 | 174 | 487 | 386 | 55 | 155 | 122 |
| 36. | Maroelana | 843 | 1534 | 1363 | 268 | 489 | 434 | 158 | 580 | 303 | 50 | 184 | 96 |
| 37. | Mayville | 419 | 1137 | 1485 | 133 | 362 | 473 | 176 | 399 | 415 | 56 | 127 | 132 |
| 38. | Menlo Park | 1400 | 1332 | 1539 | 446 | 490 | 424 | 311 | 450 | 485 | 99 | 143 | 154 |
| 39. | Meyers Park | 1021 | 791 | 963 | 325 | 252 | 307 | 219 | 355 | 197 | 70 | 133 | 62 |
| 40. | Montana | 522 | 1457 | 1482 | 166 | 464 | 472 | 200 | 356 | 327 | 64 | 113 | 104 |
| 41. | Moreleta Park | 624 | 1150 | 1344 | 199 | 366 | 428 | 173 | 418 | 369 | 55 | 133 | 117 |
| 42. | Mountain View | 1587 | 1722 | 2121 | 505 | 548 | 675 | 298 | 363 | 336 | 95 | 115 | 107 |
| 43. | Muckleneuk | 1467 | 1629 | 1914 | 467 | 519 | 610 | 341 | 282 | 340 | 109 | 89 | 108 |
| 44. | Newlands | 213 | 1161 | 1258 | 68 | 370 | 401 | 110 | 656 | 439 | 35 | 208 | 139 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation (Stem Circumference) (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BH 2004** | **BH 2019** | **GL 2019** | **DBH 2004** | **DBH 2019** | **DGL 2019** | **BH 2004** | **BH 2019** | **GL 2019** | **DBH 2004** | **DBH 2019** | **DGL 2019** |
| 45. | Nieuw Muckleneuk | 1347 | 1236 | 1355 | 429 | 394 | 429 | 250 | 401 | 430 | 80 | 127 | 136 |
| 46. | Philip Nel Park | 520 | 1333 | 1325 | 166 | 425 | 422 | 112 | 727 | 679 | 36 | 231 | 216 |
| 47. | Pretoria Central | 1420 | 1323 | 1634 | 452 | 421 | 520 | 342 | 378 | 489 | 109 | 120 | 155 |
| 48. | Pretoria Gardens | 1471 | 1394 | 1604 | 468 | 444 | 511 | 297 | 327 | 372 | 95 | 104 | 118 |
| 49. | Pretoria Industrial | 1193 | 1369 | 1576 | 380 | 436 | 502 | 193 | 292 | 228 | 61 | 92 | 72 |
| 50. | Pretoria North | 1389 | 1616 | 1745 | 442 | 515 | 556 | 277 | 317 | 293 | 88 | 100 | 93 |
| 51. | Pretoria West | 1381 | 1485 | 1606 | 440 | 415 | 511 | 205 | 639 | 664 | 65 | 203 | 211 |
| 52. | Proclamation Hill | 1345 | 1443 | 1740 | 428 | 460 | 554 | 170 | 396 | 455 | 54 | 126 | 144 |
| 53. | Queenswood | 1039 | 1104 | 1208 | 331 | 383 | 385 | 404 | 368 | 351 | 129 | 117 | 111 |
| 54. | Rietfontein | 1430 | 1650 | 1744 | 455 | 525 | 555 | 196 | 249 | 239 | 62 | 79 | 76 |
| 55. | Rietondale | 1400 | 2115 | 2375 | 446 | 673 | 756 | 340 | 427 | 492 | 108 | 135 | 156 |
| 56. | Riviera | 1497 | 2249 | 2411 | 477 | 766 | 768 | 206 | 355 | 418 | 66 | 113 | 133 |
| 57. | Saulsville | 340 | 1216 | 1293 | 108 | 339 | 412 | 85 | 396 | 313 | 27 | 126 | 99 |
| 58. | Salvokop | 1392 | 1374 | 1429 | 404 | 443 | 455 | 342 | 598 | 606 | 109 | 190 | 192 |
| 59. | Silverton | 1233 | 1546 | 1872 | 393 | 492 | 596 | 261 | 316 | 382 | 83 | 100 | 121 |
| 60. | Sinoville | 1532 | 2200 | 2216 | 488 | 699 | 706 | 251 | 655 | 530 | 80 | 208 | 168 |
| 61. | Sunnyside | 1383 | 1581 | 1830 | 440 | 583 | 474 | 227 | 308 | 316 | 72 | 98 | 100 |
| 62. | Trevena | 1312 | 1519 | 1732 | 417 | 551 | 483 | 385 | 330 | 327 | 123 | 105 | 104 |
| 63. | Valhalla | 1256 | 1715 | 1739 | 400 | 548 | 507 | 270 | 442 | 465 | 86 | 140 | 148 |
| 64. | Villiera | 1410 | 1513 | 1897 | 449 | 604 | 481 | 271 | 306 | 350 | 86 | 97 | 111 |
| 65. | Waterkloof | 1538 | 1734 | 1739 | 489 | 553 | 536 | 288 | 703 | 502 | 92 | 223 | 159 |
| 66. | Waterkloof Glen | 805 | 1041 | 1277 | 256 | 406 | 331 | 170 | 220 | 298 | 54 | 70 | 94 |
| 67. | Waterkloof Park | 824 | 1511 | 1457 | 262 | 464 | 453 | 224 | 672 | 460 | 71 | 214 | 146 |
| 68. | Waterkloof Ridge | 1102 | 1568 | 1548 | 350 | 492 | 485 | 176 | 542 | 366 | 56 | 172 | 116 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation (Stem Circumference) (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BH 2004** | **BH 2019** | **GL 2019** | **DBH 2004** | **DBH 2019** | **DGL 2019** | **BH 2004** | **BH 2019** | **GL 2019** | **DBH 2004** | **DBH 2019** | **DGL 2019** |
| 69. | Watloo | 1063 | 1721 | 1681 | 338 | 535 | 525 | 215 | 243 | 229 | 62 | 77 | 72 |
| 70. | Wes Park | 1159 | 1576 | 1826 | 369 | 581 | 501 | 196 | 464 | 356 | 68 | 147 | 113 |
| 71. | Wingate Park | 195 | 1363 | 1178 | 62 | 375 | 341 | 64 | 592 | 273 | 20 | 188 | 86 |
| 72. | Wonderboom South | 1552 | 1853 | 2135 | 494 | 679 | 590 | 297 | 386 | 435 | 95 | 122 | 138 |

Table 4.3 shows the suburb names, the mean Stem Circumference at Breast Height (BH) and Ground Level (GL), the Mean Stem Diameter at Breast Height (DBH) and at Ground Level (DGL) as well as the standard deviation (mm) for both Stem Circumference and Diameter and the standard deviation (mm) in 2004 and 2019. The data in the table is presented in *descending order* for 2004.

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation (Stem Circumference) (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 |
| 1. | Asiatic Bazaar | 1687 | 2115 | 2061 | 536 | 656 | 320 | 320 | 451 | 315 | 101 | 100 | 143 |
| 2. | Laudium | 1671 | 1992 | 2093 | 532 | 604 | 667 | 245 | 583 | 463 | 78 | 147 | 185 |
| 3. | Claremont | 1644 | 1995 | 2175 | 524 | 602 | 693 | 316 | 661 | 490 | 100 | 156 | 150 |
| 4. | Colbyn | 1616 | 1994 | 2264 | 515 | 635 | 721 | 263 | 300 | 343 | 83 | 109 | 95 |
| 5. | Mountain View | 1587 | 1928 | 2121 | 505 | 548 | 675 | 298 | 363 | 336 | 94 | 107 | 115 |
| 6. | Wonderboom South | 1552 | 1853 | 2135 | 494 | 679 | 590 | 297 | 386 | 435 | 94 | 138 | 122 |
| 7. | Waterkloof | 1538 | 1734 | 1739 | 489 | 553 | 536 | 288 | 703 | 502 | 91 | 159 | 223 |
| 8. | Sinoville | 1532 | 2200 | 2216 | 488 | 699 | 706 | 251 | 655 | 530 | 79 | 168 | 208 |
| 9. | Riviera | 1497 | 2249 | 2411 | 477 | 766 | 768 | 206 | 355 | 418 | 65 | 133 | 113 |
| 10. | Pretoria Gardens | 1471 | 1394 | 1604 | 468 | 444 | 511 | 297 | 327 | 372 | 94 | 118 | 104 |
| 11. | Muckleneuk | 1467 | 1629 | 1914 | 467 | 519 | 610 | 341 | 282 | 340 | 108 | 108 | 89 |
| 12. | Brooklyn | 1446 | 1404 | 1620 | 461 | 493 | 516 | 187 | 296 | 333 | 59 | 121 | 123 |
| 13. | Rietfontein | 1430 | 1650 | 1744 | 455 | 525 | 555 | 196 | 249 | 239 | 62 | 76 | 79 |
| 14. | Pretoria Central | 1420 | 1323 | 1634 | 452 | 421 | 520 | 342 | 378 | 489 | 108 | 155 | 120 |
| 15. | Villiera | 1410 | 1513 | 1897 | 449 | 604 | 481 | 271 | 306 | 350 | 86 | 111 | 97 |
| 16. | Ellofsdal | 1403 | 1365 | 1603 | 447 | 435 | 511 | 402 | 274 | 317 | 128 | 100 | 87 |
| 17. | Rietondale | 1400 | 2115 | 2375 | 446 | 673 | 756 | 340 | 427 | 492 | 108 | 156 | 135 |
| 18. | Menlo Park | 1400 | 1332 | 1539 | 446 | 490 | 424 | 311 | 450 | 485 | 99 | 154 | 143 |
| 19. | Lynwood | 1395 | 1912 | 1645 | 444 | 510 | 524 | 486 | 1052 | 547 | 154 | 174 | 335 |
| 20. | Salvokop | 1392 | 1374 | 1429 | 404 | 443 | 455 | 342 | 746 | 612 | 108 | 192 | 190 |
| 21. | Pretoria North | 1389 | 1616 | 1745 | 442 | 515 | 556 | 277 | 317 | 293 | 88 | 93 | 100 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation (Stem Circumference) (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 |
| 22. | Sunnyside | 1383 | 1581 | 1830 | 440 | 583 | 474 | 227 | 326 | 355 | 72 | 100 | 98 |
| 23. | Pretoria West | 1381 | 1485 | 1606 | 440 | 415 | 511 | 205 | 639 | 664 | 65 | 211 | 203 |
| 24. | Nieuw Mucklenuek | 1347 | 1236 | 1355 | 429 | 394 | 429 | 250 | 401 | 430 | 79 | 136 | 127 |
| 25. | Proclamation Hill | 1345 | 1443 | 1740 | 428 | 460 | 554 | 170 | 396 | 455 | 54 | 144 | 126 |
| 26. | Hatfield | 1332 | 1508 | 1727 | 424 | 480 | 550 | 171 | 247 | 279 | 54 | 88 | 78 |
| 27. | Lisdogan Park | 1331 | 1508 | 1565 | 424 | 493 | 498 | 338 | 580 | 434 | 107 | 138 | 184 |
| 28. | Trevena | 1312 | 1519 | 1732 | 417 | 551 | 483 | 385 | 330 | 327 | 122 | 104 | 105 |
| 29. | Arcadia | 1302 | 1483 | 1761 | 415 | 472 | 561 | 199 | 211 | 285 | 63 | 90 | 67 |
| 30. | Kwaggasrand | 1286 | 1616 | 1868 | 410 | 592 | 595 | 166 | 350 | 327 | 52 | 104 | 111 |
| 31. | Valhalla | 1256 | 1715 | 1739 | 400 | 548 | 507 | 270 | 472 | 371 | 85 | 148 | 140 |
| 32. | Silverton | 1233 | 1548 | 1872 | 393 | 492 | 596 | 261 | 316 | 382 | 83 | 121 | 100 |
| 33. | Annlin | 1218 | 1757 | 1835 | 388 | 535 | 584 | 417 | 451 | 368 | 132 | 117 | 143 |
| 34. | Clydesdale | 1216 | 1555 | 1794 | 387 | 465 | 571 | 236 | 530 | 382 | 75 | 111 | 105 |
| 35. | Pretoria Industrial | 1193 | 1369 | 1576 | 380 | 436 | 502 | 193 | 292 | 228 | 61 | 72 | 92 |
| 36. | Wespark | 1159 | 1576 | 1826 | 369 | 581 | 501 | 196 | 243 | 229 | 62 | 72 | 77 |
| 37. | Danville | 1129 | 1543 | 1783 | 360 | 491 | 568 | 254 | 392 | 449 | 80 | 142 | 124 |
| 38. | Lynwood Glen | 1108 | 1256 | 1440 | 353 | 400 | 459 | 187 | 278 | 324 | 59 | 103 | 88 |
| 39. | Waterkloof Ridge | 1102 | 1568 | 1548 | 350 | 492 | 485 | 176 | 542 | 366 | 56 | 116 | 172 |
| 40. | Eastwood | 1098 | 1027 | 1165 | 350 | 327 | 371 | 288 | 323 | 264 | 91 | 84 | 102 |
| 41. | Lukasrand | 1089 | 1189 | 1431 | 347 | 379 | 456 | 252 | 233 | 373 | 80 | 86 | 74 |
| 42. | Watloo | 1063 | 1721 | 1681 | 338 | 535 | 525 | 215 | 464 | 356 | 68 | 113 | 147 |
| 43. | Ashlea Gardens | 1060 | 1554 | 1504 | 338 | 435 | 479 | 389 | 511 | 253 | 123 | 80 | 162 |
| 44. | Eersterust | 1049 | 1767 | 1860 | 334 | 563 | 592 | 257 | 447 | 380 | 81 | 121 | 142 |
| 45. | Queenswood | 1039 | 1104 | 1208 | 331 | 383 | 385 | 404 | 368 | 351 | 128 | 111 | 117 |
| 46. | Hillcrest | 1027 | 1179 | 1452 | 327 | 375 | 462 | 264 | 341 | 423 | 84 | 134 | 108 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation (Stem Circumference) (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 |
| 47. | Meyers Park | 1021 | 890 | 963 | 325 | 252 | 307 | 219 | 355 | 197 | 69 | 62 | 133 |
| 48. | Alphen Park | 913 | 1269 | 1395 | 291 | 439 | 444 | 258 | 491 | 454 | 82 | 144 | 156 |
| 49. | La Montagne | 898 | 1694 | 1525 | 286 | 441 | 486 | 310 | 552 | 359 | 98 | 114 | 175 |
| 50. | Constantia Park | 848 | 1034 | 1270 | 270 | 329 | 404 | 175 | 217 | 291 | 55 | 92 | 69 |
| 51. | Maroelana | 843 | 1534 | 1363 | 268 | 489 | 434 | 158 | 580 | 386 | 50 | 96 | 184 |
| 52. | Waterkloof Park | 824 | 1511 | 1457 | 262 | 464 | 453 | 224 | 672 | 460 | 71 | 146 | 214 |
| 53. | Garsfontein | 818 | 1269 | 1353 | 261 | 357 | 431 | 191 | 659 | 447 | 60 | 148 | 141 |
| 54. | Attridgeville | 814 | 1423 | 1254 | 341 | 399 | 119 | 119 | 542 | 331 | 37 | 105 | 172 |
| 55. | Kilner Park | 810 | 1270 | 1436 | 258 | 456 | 457 | 207 | 374 | 347 | 65 | 110 | 119 |
| 56. | Waterkloof Glen | 805 | 1041 | 1277 | 256 | 406 | 331 | 170 | 220 | 298 | 54 | 94 | 70 |
| 57. | Erasmusrand | 773 | 975 | 1136 | 124 | 351 | 439 | 204 | 270 | 265 | 64 | 84 | 85 |
| 58. | Mamelodi | 736 | 1339 | 1410 | 234 | 426 | 449 | 174 | 487 | 386 | 55 | 122 | 155 |
| 59. | Jan Niemand Park | 669 | 1293 | 1343 | 213 | 349 | 428 | 273 | 428 | 328 | 86 | 87 | 77 |
| 60. | Lynnwood Ridge | 626 | 1297 | 1383 | 199 | 436 | 440 | 156 | 540 | 354 | 49 | 112 | 171 |
| 61. | Moreleta Park | 624 | 1197 | 1344 | 199 | 366 | 428 | 173 | 418 | 369 | 55 | 117 | 133 |
| 62. | Hazelwood | 523 | 1371 | 1497 | 167 | 410 | 477 | 347 | 665 | 501 | 110 | 159 | 211 |
| 63. | Montana | 522 | 1498 | 1482 | 166 | 464 | 472 | 200 | 356 | 327 | 63 | 104 | 113 |
| 64. | Faerie Glen | 522 | 1388 | 1536 | 166 | 384 | 489 | 124 | 451 | 402 | 39 | 94 | 77 |
| 65. | Philip Nel Park | 520 | 1333 | 1325 | 166 | 425 | 422 | 112 | 727 | 679 | 35 | 216 | 231 |
| 66. | Mayville | 419 | 1340 | 1485 | 133 | 362 | 473 | 176 | 399 | 415 | 56 | 132 | 127 |
| 67. | Erasmuskloof | 390 | 1351 | 1380 | 246 | 311 | 362 | 162 | 474 | 473 | 51 | 112 | 94 |
| 68. | Saulville | 340 | 1216 | 1293 | 108 | 339 | 412 | 85 | 396 | 131 | 27 | 99 | 126 |
| 69. | Elardus Park | 323 | 958 | 434 | 103 | 305 | 361 | 91 | 241 | 208 | 28 | 66 | 76 |
| 70. | Hestea Park | 278 | 2369 | 2295 | 89 | 544 | 731 | 85 | 1236 | 929 | 27 | 236 | 200 |
| 71. | Newlands | 213 | 1287 | 1258 | 68 | 370 | 401 | 110 | 656 | 439 | 35 | 139 | 208 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation (Stem Circumference) (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 |
| 72. | Wingate Park | 195 | 1363 | 1178 | 62 | 375 | 341 | 64 | 592 | 273 | 20 | 86 | 188 |

Table 4.4 shows the suburb names, the mean stem circumference at Breast Height (DBH) and Ground Level (DGL), the Mean Stem Diameter at Breast Height (DBH) and at Ground Level (DGL) as well as the standard deviation (mm) for both Stem Circumference and Diameter and the standard deviation (mm) for 2004 and 2019. The table shows the data collected in 2019 in comparison to the data collected in 2004 in *descending order* for 2019.

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation Stem Circumference (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 |
| 1. | Hestea Park | 278 | 2369 | 2295 | 89 | 544 | 731 | 85 | 1236 | 929 | 27 | 200 | 236 |
| 2. | Riviera | 1497 | 2249 | 2411 | 477 | 766 | 768 | 206 | 355 | 418 | 65 | 113 | 133 |
| 3. | Sinoville | 1532 | 2200 | 2216 | 488 | 699 | 706 | 251 | 655 | 530 | 79 | 208 | 168 |
| 4. | Rietondale | 1400 | 2115 | 2375 | 446 | 673 | 756 | 340 | 427 | 492 | 108 | 135 | 156 |
| 5. | Asiatic Bazaar | 1687 | 2115 | 2061 | 536 | 656 | 320 | 320 | 451 | 315 | 101 | 143 | 100 |
| 6. | Claremont | 1644 | 1995 | 2175 | 524 | 602 | 693 | 316 | 661 | 490 | 100 | 150 | 156 |
| 7. | Colbyn | 1616 | 1994 | 2264 | 515 | 635 | 721 | 263 | 300 | 343 | 83 | 95 | 109 |
| 8. | Laudium | 1671 | 1992 | 2093 | 532 | 604 | 667 | 245 | 583 | 463 | 78 | 185 | 147 |
| 9. | Mountain View | 1587 | 1928 | 2121 | 505 | 548 | 675 | 298 | 363 | 336 | 94 | 115 | 107 |
| 10. | Lynwood | 1395 | 1912 | 1645 | 444 | 510 | 524 | 486 | 1052 | 547 | 154 | 335 | 174 |
| 11. | Wonderboom South | 1552 | 1853 | 2153 | 494 | 679 | 590 | 297 | 386 | 435 | 94 | 122 | 138 |
| 12. | Eersterust | 1049 | 1767 | 1860 | 334 | 563 | 592 | 257 | 447 | 380 | 81 | 142 | 121 |
| 13. | Annlin | 1218 | 1757 | 1835 | 388 | 535 | 584 | 417 | 451 | 368 | 132 | 143 | 117 |
| 14. | Waterkloof | 1538 | 1734 | 1739 | 489 | 553 | 536 | 288 | 703 | 502 | 91 | 223 | 159 |
| 15. | Watloo | 1063 | 1721 | 1681 | 338 | 535 | 525 | 215 | 464 | 355 | 68 | 147 | 113 |
| 16. | Valhalla | 1256 | 1715 | 1739 | 400 | 548 | 507 | 270 | 472 | 371 | 85 | 140 | 148 |
| 17. | La Montagne | 898 | 1694 | 1525 | 286 | 441 | 486 | 310 | 552 | 359 | 98 | 175 | 114 |
| 18. | Rietfontein | 1430 | 1650 | 1744 | 455 | 525 | 555 | 196 | 249 | 239 | 62 | 79 | 76 |
| 19. | Muckleneuk | 1467 | 1629 | 1914 | 467 | 519 | 610 | 341 | 282 | 340 | 108 | 89 | 108 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation Stem Circumference (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 |
| 20. | Kwaggasrand | 1286 | 1616 | 1868 | 410 | 592 | 595 | 166 | 320 | 327 | 52 | 111 | 104 |
| 21. | Pretoria North | 1389 | 1616 | 1745 | 442 | 515 | 556 | 277 | 317 | 293 | 88 | 100 | 93 |
| 22. | Sunnyside | 1383 | 1581 | 1830 | 440 | 583 | 474 | 227 | 326 | 355 | 72 | 98 | 100 |
| 23. | Wespark | 1159 | 1576 | 1826 | 369 | 581 | 501 | 243 | 243 | 229 | 62 | 77 | 72 |
| 24. | Waterkloof Ridge | 1102 | 1568 | 1548 | 350 | 492 | 485 | 176 | 542 | 366 | 56 | 172 | 116 |
| 25. | Clydesdale | 1216 | 1555 | 1794 | 387 | 465 | 571 | 236 | 530 | 382 | 75 | 105 | 111 |
| 26. | Ashlea Gardens | 1060 | 1554 | 1504 | 338 | 435 | 479 | 389 | 511 | 253 | 123 | 162 | 80 |
| 27. | Silverton | 1233 | 1548 | 1872 | 393 | 492 | 596 | 261 | 316 | 382 | 83 | 100 | 121 |
| 28. | Danville | 1129 | 1543 | 1783 | 360 | 491 | 568 | 254 | 392 | 449 | 80 | 124 | 142 |
| 29. | Maroelana | 843 | 1534 | 1363 | 268 | 489 | 434 | 158 | 580 | 303 | 50 | 184 | 96 |
| 30. | Trevena | 1312 | 1519 | 1732 | 417 | 551 | 483 | 385 | 330 | 327 | 122 | 105 | 104 |
| 31. | Villiera | 1410 | 1513 | 1897 | 449 | 604 | 481 | 271 | 306 | 350 | 85 | 140 | 148 |
| 32. | Waterkloof Park | 824 | 1511 | 1457 | 262 | 464 | 453 | 224 | 672 | 460 | 71 | 214 | 146 |
| 33. | Hatfield | 1332 | 1508 | 1727 | 424 | 480 | 550 | 171 | 247 | 279 | 54 | 78 | 88 |
| 34. | Lisdogan Park | 1331 | 1508 | 1565 | 424 | 493 | 498 | 338 | 580 | 434 | 107 | 184 | 138 |
| 35. | Montana | 522 | 1498 | 1482 | 166 | 464 | 472 | 200 | 356 | 327 | 63 | 113 | 104 |
| 36. | Pretoria West | 1381 | 1485 | 1606 | 440 | 415 | 511 | 205 | 639 | 664 | 65 | 203 | 211 |
| 37. | Arcadia | 1302 | 1483 | 1761 | 415 | 472 | 561 | 199 | 211 | 285 | 63 | 67 | 90 |
| 38. | Proclamation Hill | 1345 | 1443 | 1740 | 428 | 460 | 554 | 170 | 396 | 455 | 54 | 126 | 144 |
| 39. | Attridgeville | 814 | 1423 | 1254 | 341 | 399 | 119 | 119 | 542 | 331 | 37 | 172 | 105 |
| 40. | Brooklyn | 1446 | 1404 | 1625 | 461 | 493 | 516 | 187 | 296 | 333 | 59 | 123 | 121 |
| 41. | Pretoria Gardens | 1471 | 1394 | 1604 | 468 | 444 | 511 | 297 | 327 | 372 | 94 | 104 | 118 |
| 42. | Faerie Glen | 522 | 1388 | 1536 | 166 | 384 | 489 | 124 | 451 | 402 | 39 | 77 | 94 |
| 43. | Salvokop | 1392 | 1374 | 1429 | 404 | 443 | 455 | 342 | 746 | 612 | 108 | 190 | 192 |
| 44. | Hazelwood | 523 | 1371 | 1497 | 167 | 410 | 477 | 347 | 665 | 501 | 110 | 211 | 159 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation Stem Circumference (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 | BH 2004 | BH 2019 | GL 2019 | DBH 2004 | DBH 2019 | DGL 2019 |
| 45. | Pretoria Industrial | 1193 | 1369 | 1576 | 380 | 436 | 502 | 193 | 292 | 228 | 61 | 92 | 72 |
| 46. | Eloffsdal | 1403 | 1365 | 1603 | 447 | 435 | 511 | 402 | 274 | 317 | 128 | 87 | 100 |
| 47. | Wingate Park | 195 | 1363 | 1178 | 62 | 375 | 341 | 64 | 592 | 273 | 20 | 188 | 86 |
| 48. | Erasmuskloof | 390 | 1351 | 1380 | 246 | 311 | 362 | 162 | 474 | 473 | 51 | 94 | 112 |
| 49. | Mayville | 419 | 1340 | 1485 | 133 | 362 | 473 | 176 | 399 | 415 | 56 | 127 | 132 |
| 50. | Mamelodi | 736 | 1339 | 1410 | 234 | 426 | 449 | 174 | 487 | 386 | 55 | 155 | 122 |
| 51. | Philip Nel Park | 520 | 1333 | 1325 | 166 | 425 | 422 | 112 | 727 | 679 | 35 | 231 | 216 |
| 52. | Menlo Park | 1400 | 1332 | 1539 | 446 | 490 | 424 | 311 | 450 | 485 | 99 | 143 | 154 |
| 53. | Pretoria Central | 1420 | 1323 | 1634 | 452 | 421 | 520 | 342 | 378 | 489 | 108 | 120 | 155 |
| 54. | Lynwood Ridge | 626 | 1297 | 1383 | 199 | 436 | 440 | 156 | 540 | 354 | 49 | 171 | 112 |
| 55. | Jan Niemand Park | 669 | 1293 | 1343 | 213 | 349 | 428 | 273 | 428 | 328 | 86 | 77 | 87 |
| 56. | Newlands | 213 | 1287 | 1258 | 68 | 370 | 401 | 110 | 656 | 439 | 35 | 208 | 139 |
| 57. | Kilner Park | 810 | 1270 | 1436 | 258 | 456 | 457 | 207 | 374 | 347 | 65 | 119 | 110 |
| 58. | Alphen Park | 913 | 1269 | 1395 | 291 | 439 | 444 | 258 | 491 | 454 | 82 | 156 | 144 |
| 59. | Garsfontein | 818 | 1269 | 1353 | 261 | 357 | 431 | 191 | 659 | 447 | 60 | 141 | 148 |
| 60. | Lynwood Glen | 1108 | 1256 | 1440 | 353 | 400 | 459 | 187 | 278 | 324 | 59 | 88 | 103 |
| 61. | Nieuw Muckleneuk | 1347 | 1236 | 1355 | 429 | 394 | 429 | 250 | 401 | 430 | 79 | 127 | 136 |
| 62. | Saulsville | 340 | 1216 | 1293 | 108 | 339 | 412 | 85 | 396 | 313 | 27 | 126 | 99 |
| 63. | Moreleta Park | 624 | 1197 | 1344 | 199 | 366 | 428 | 173 | 418 | 369 | 55 | 133 | 117 |
| 64. | Lukasrand | 1089 | 1189 | 1431 | 347 | 379 | 456 | 252 | 233 | 273 | 80 | 74 | 86 |
| 65. | Hillcrest | 1027 | 1179 | 1452 | 327 | 375 | 462 | 264 | 341 | 423 | 84 | 108 | 134 |
| 66. | Queenswood | 1039 | 1104 | 1208 | 331 | 383 | 385 | 404 | 368 | 351 | 128 | 117 | 111 |
| 67. | Waterkloof Glen | 805 | 1041 | 1277 | 256 | 406 | 331 | 170 | 220 | 298 | 54 | 70 | 94 |
| 68. | Constantia Park | 848 | 1034 | 1270 | 270 | 329 | 404 | 175 | 217 | 291 | 55 | 69 | 92 |
| 69. | Eastwood | 1098 | 1027 | 1165 | 350 | 327 | 371 | 288 | 323 | 264 | 91 | 102 | 84 |

| | Suburb | Mean Stem Circumference (mm) | | | Mean Stem Diameter (mm) | | | Standard Deviation Stem Circumference (mm) | | | Standard Deviation (Diameter) (mm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BH 2004** | **BH 2019** | **GL 2019** | **DBH 2004** | **DBH 2019** | **DGL 2019** | **BH 2004** | **BH 2019** | **GL 2019** | **DBH 2004** | **DBH 2019** | **DGL 2019** |
| 70. | Erasmusrand | 773 | 975 | 1136 | 124 | 351 | 439 | 204 | 270 | 265 | 64 | 85 | 84 |
| 71. | Elardus Park | 323 | 958 | 1134 | 103 | 305 | 361 | 91 | 241 | 208 | 28 | 76 | 66 |
| 72. | Meyers Park | 1021 | 890 | 963 | 325 | 252 | 307 | 219 | 355 | 197 | 69 | 133 | 62 |


Figure 4.2: Map illustrating the Mean Stem Circumference (mm) at Breast Height for 2019. The darker colours are representative of the suburbs with the highest Mean Stem Circumference (mm) at Breast Height values.


Figure 4.3: Map illustrating the Mean Stem Circumference (mm) at Ground Level for 2019. The darker colours are representative of the suburbs with the highest Mean Stem Circumference (mm) values at Ground Level.

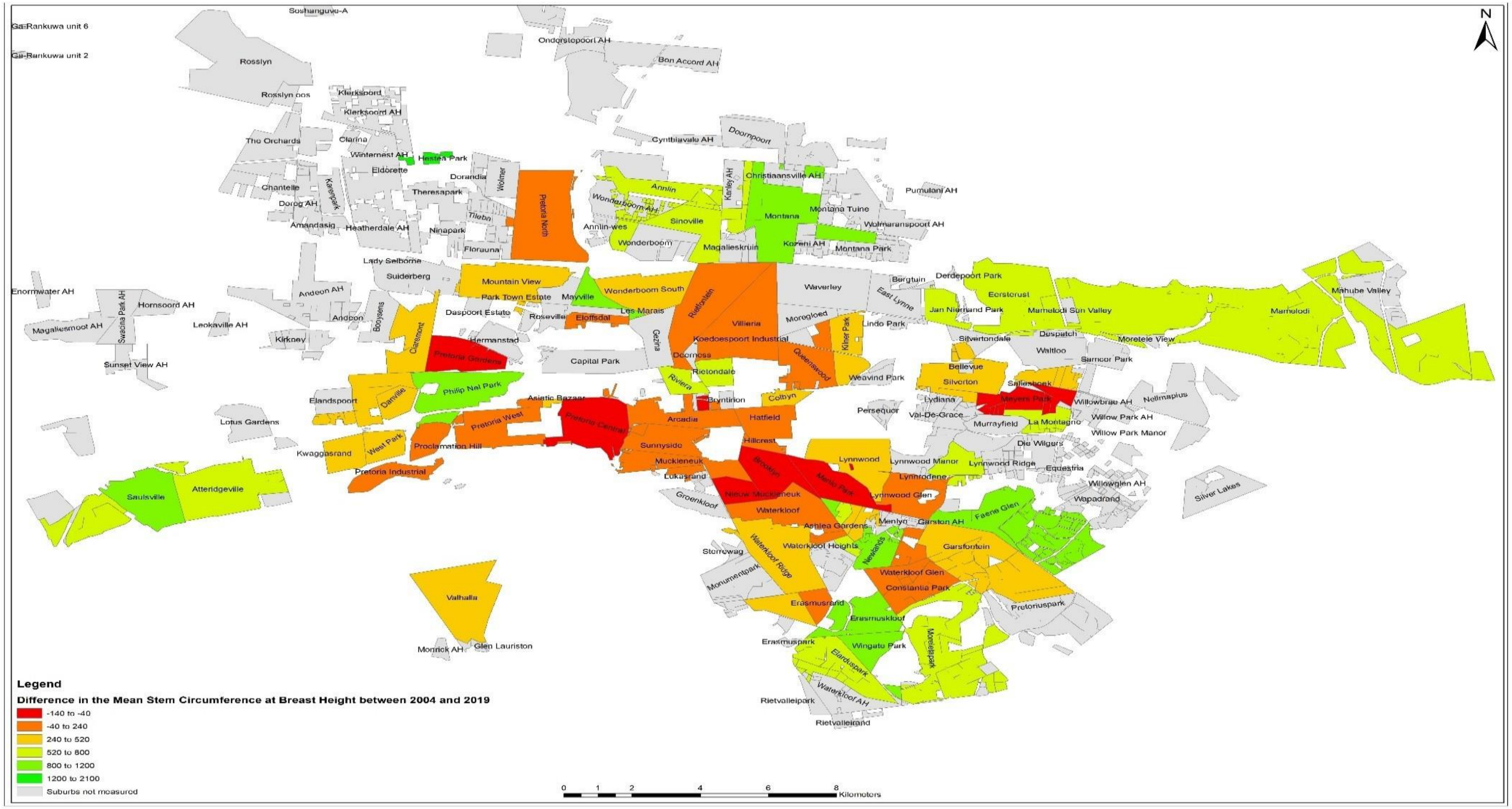


Figure 4.4: Map comparing the Mean Stem Circumference (mm) at Breast Height in 2004 and 2019. The negative values reflect a net reduction of the stem circumference since 2004 and positive values reflect a net increase in the stem circumference since 2004.

### 4.2.2. Mean Carbon per tree and Total Carbon per suburb

Table 4.5 shows the number of trees per suburb, the Mean Carbon (tonne) per tree and Total Carbon (tonne) per suburb in alphabetical order. The table also provides the Total Carbon percentage of each suburb in relation to the Total Carbon for all suburbs.

Table 4.6 shows the Mean Carbon tonne) per tree and Total Carbon (tonne) per suburb in descending order for the baseline study (2004). In the baseline study suburbs with the highest mean carbon values were Asiatic Bazaar, Laudium, Claremont and Colbyn with mean carbon values of 0.713 t C, 0.680 t C, 0.670 t C and 0.631 t C, respectively. Suburbs with the lowest mean carbon values were Elardus Park, Hestea Park, Newlands and Wingate Park with mean carbon values 0.013 t C, 0.009 t C, 0.006 t C and 0.004 t C, respectively.

Table 4.7 shows the Mean Carbon (tonne) per tree and Total Carbon (tonne) per suburb in descending order for this study. Suburbs with the highest mean carbon were Riviera, Rietondale, Colbyn and Sinoville with Mean Carbon values of 1.273 t C, 1.226 t C, 1.088 t C and 1.032 t C, respectively. Suburbs with the lowest mean carbon values were Wingate Park, Atteridgeville, Saulsville and Meyers Park with mean carbon values of 0.169 t C, 0.168 t C, 0.167 t C and 0.079 t C, respectively.

Table 4.5 shows the suburb name, the total number (n) of Jacaranda trees in each suburb, the Mean Carbon (tonne) per tree, the Total Carbon (tonne) per suburb and the percentage per suburb in relation to the Total Carbon for all the suburbs in 2004 and 2019 in *alphabetical* order.

| **No.** | **Suburb** | **n** | **Mean t C per tree** | | **Total t C per suburb** | | **% of Total t C** | |
|---|---|---|---|---|---|---|---|---|
| | | **2004/2019** | **2004** | **2019** | **2004** | **2019** | **2004** | **2019** |
| 1 | Alphen Park | 96 | 0.165 | 0.326 | 15.82 | 31.35 | 0.13 | 0.18 |
| 2 | Annlin | 492 | 0.359 | 0.645 | 176.62 | 317.70 | 1.44 | 1.97 |
| 3 | Arcadia | 1929 | 0.367 | 0.582 | 798.77 | 1124.46 | 5.80 | 6.46 |
| 4 | Asiatic Bazaar | 67 | 0.713 | 0.520 | 47.79 | 34.89 | 0.39 | 0.21 |
| 5 | Ashlea Gardens | 409 | 0.263 | 0.309 | 107.49 | 126.55 | 0.88 | 0.78 |
| 6 | Atteridgeville | 268 | 0.114 | 0.168 | 30.54 | 45.26 | 0.25 | 0.28 |
| 7 | Brooklyn | 2535 | 0.472 | 0.473 | 1195.35 | 1200.82 | 9.79 | 6.90 |
| 8 | Claremont | 344 | 0.670 | 0.985 | 230.64 | 338.97 | 1.88 | 1.94 |
| 9 | Clydesdale | 67 | 0.317 | 0.610 | 21.26 | 40.90 | 0.17 | 0.23 |
| 10 | Colbyn | 308 | 0.631 | 1.088 | 194.43 | 335.31 | 1.59 | 1.92 |
| 11 | Constantia Park | 393 | 0.131 | 0.258 | 51.38 | 101.64 | 0.42 | 0.58 |
| 12 | Danville | 67 | 0.269 | 0.601 | 18.05 | 40.28 | 0.148 | 0.23 |
| 13 | Eastwood | 499 | 0.259 | 0.208 | 104.13 | 129.20 | 1.05 | 0.59 |
| 14 | Eersterust | 442 | 0.228 | 0.667 | 100.60 | 295.18 | 0.82 | 1.69 |
| 15 | Elardus Park | 159 | 0.013 | 0.195 | 2.00 | 31.02 | 0.016 | 0.17 |
| 16 | Eloffsdal | 159 | 0.487 | 0.461 | 77.39 | 73.36 | 0.63 | 0.42 |
| 17 | Erasmuskloof | 70 | 0.023 | 0.317 | 1.65 | 22.25 | 0.01 | 0.12 |
| 18 | Erasmusrand | 227 | 0.109 | 0.196 | 24.69 | 44.49 | 0.202 | 0.25 |
| 19 | Faerie Glen | 223 | 0.040 | 0.414 | 8.88 | 92.53 | 0.073 | 0.53 |
| 20 | Garsfontein | 449 | 0.122 | 0.302 | 54.67 | 135.91 | 0.44 | 0.78 |
| 21 | Hatfield | 977 | 0.385 | 0.555 | 375.98 | 542.57 | 3.08 | 3.12 |
| 22 | Hazelwood | 77 | 0.067 | 0.389 | 5.197 | 29.97 | 0.04 | 0.17 |

| No. | Suburb | n | Mean t C per tree | | Total t C per suburb | | % of Total t C | |
|---|---|---|---|---|---|---|---|---|
| | | 2004/2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 23 | Hestea Park | 103 | 0.009 | 1.126 | 0.913 | 115.99 | 0.007 | 0.66 |
| 24 | Hillcrest | 155 | 0.218 | 0.360 | 33.85 | 55.92 | 0.27 | 0.32 |
| 25 | Jan Niemand Park | 61 | 0.088 | 0.297 | 5.37 | 18.12 | 0.04 | 0.10 |
| 26 | Kilner Park | 235 | 0.121 | 0.35 | 28.40 | 82.48 | 0.23 | 0.47 |
| 27 | Kwaggasrand | 310 | 0.352 | 0.675 | 109.05 | 209.25 | 0.89 | 1.20 |
| 28 | La Montagne | 59 | 0.170 | 0.407 | 10.04 | 24.04 | 0.08 | 0.13 |
| 29 | Laudium | 281 | 0.680 | 0.895 | 191.18 | 251.66 | 1.56 | 1.44 |
| 30 | Lisdogan Park | 531 | 0.415 | 0.434 | 220.38 | 230.83 | 1.80 | 1.32 |
| 31 | Lukasrand | 323 | 0.248 | 0.347 | 80.04 | 112.39 | 0.65 | 0.64 |
| 32 | Lynnwood | 514 | 0.508 | 0.492 | 252.930 | 261.11 | 2.13 | 1.45 |
| 33 | Lynnwood Glen | 102 | 0.248 | 0.353 | 25.31 | 36.05 | 0.20 | 0.20 |
| 34 | Lynnwood Ridge | 108 | 0.063 | 0.319 | 6.85 | 34.52 | 0.056 | 0.19 |
| 35 | Mamelodi | 304 | 0.094 | 0.335 | 28.54 | 101.96 | 0.23 | 0.58 |
| 36 | Maroelana | 60 | 0.127 | 0.308 | 7.61 | 18.49 | 0.06 | 0.10 |
| 37 | Mayville | 42 | 0.028 | 0.381 | 1.15 | 16.02 | 0.009 | 0.09 |
| 38 | Menlo Park | 378 | 0.458 | 0.416 | 173.31 | 157.61 | 1.42 | 0.90 |
| 39 | Meyers Park | 235 | 0.208 | 0.079 | 48.85 | 18.72 | 0.400 | 0.11 |
| 40 | Montana | 93 | 0.045 | 0.379 | 4.19 | 35.30 | 0.034 | 0.20 |
| 41 | Moreleta Park | 348 | 0.065 | 0.297 | 22.45 | 103.61 | 0.18 | 0.59 |
| 42 | Mountain View | 153 | 0.612 | 0.925 | 93.64 | 141.62 | 0.76 | 0.81 |
| 43 | Muckleneuk | 559 | 0.520 | 0.717 | 290.64 | 400.85 | 2.38 | 2.30 |
| 44 | Newlands | 60 | 0.006 | 0.252 | 0.346 | 15.15 | 0.003 | 0.08 |
| 45 | Nieuw Muckleneuk | 284 | 0.407 | 0.303 | 115.72 | 86.28 | 0.94 | 0.49 |
| 46 | Philip Nel Park | 56 | 0.039 | 0.287 | 2.18 | 16.09 | 0.01 | 0.09 |
| 47 | Pretoria Central | 2853 | 0.483 | 0.483 | 1379.03 | 1380.68 | 11.29 | 7.94 |
| 48 | Pretoria Gardens | 132 | 0.511 | 0.462 | 67.44 | 61.00 | 0.55 | 0.35 |

| No. | Suburb | n | Mean t C per tree | | Total t C per suburb | | % of Total t C | |
|---|---|---|---|---|---|---|---|---|
| | | 2004/2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 49 | Pretoria Industrial | 396 | 0.297 | 0.442 | 117.62 | 175.17 | 0.96 | 1.00 |
| 50 | Pretoria North | | 0.443 | 0.569 | 372.49 | 478.67 | 3.05 | 2.75 |
| 51 | Pretoria West | 702 | 0.424 | 0.463 | 297.84 | 325.43 | 2.44 | 1.87 |
| 52 | Proclamation Hill | 896 | 0.393 | 0.565 | 352.15 | 506.95 | 2.916 | 2.88 |
| 53 | Queenswood | 215 | 0.253 | 0.228 | 54.31 | 49.00 | 0.44 | 0.28 |
| 54 | Rietfontein | 1028 | 0.460 | 0.569 | 473.02 | 584.97 | 3.87 | 3.36 |
| 55 | Rietondale | 454 | 0.467 | 1.226 | 211.94 | 556.73 | 1.73 | 3.20 |
| 56 | Riviera | 465 | 0.516 | 1.273 | 239.76 | 591.95 | 1.96 | 3.40 |
| 57 | Saulsville | 208 | 0.014 | 0.270 | 2.90 | 56.24 | 0.02 | 0.32 |
| 58 | Salvokop | 87 | 0.464 | 0.346 | 40.15 | 30.16 | 0.32 | 0.17 |
| 59 | Silverton | 166 | 0.332 | 0.678 | 55.08 | 112.64 | 0.45 | 0.64 |
| 60 | Sinoville | 82 | 0.553 | 1.032 | 45.35 | 84.64 | 0.37 | 0.48 |
| 61 | Sunnyside | 1836 | 0.430 | 0.641 | 788.65 | 1177.57 | 6.46 | 6.77 |
| 62 | Trevena | 128 | 0.415 | 0.559 | 53.11 | 71.59 | 0.43 | 0.41 |
| 63 | Valhalla | 447 | 0.348 | 0.564 | 155.68 | 252.55 | 1.27 | 1.45 |
| 64 | Villiera | 1270 | 0.458 | 0.701 | 552.80 | 846.54 | 4.52 | 4.86 |
| 65 | Waterkloof | 1412 | 0.568 | 0.564 | 801.35 | 797.76 | 6.56 | 4.58 |
| 66 | Waterkloof Glen | 155 | 0.115 | 0.262 | 17.82 | 40.63 | 0.146 | 0.23 |
| 67 | Waterkloof Park | 189 | 0.127 | 0.363 | 24.09 | 68.77 | 0.197 | 0.39 |
| 68 | Waterkloof Ridge | 1509 | 0.243 | 0.423 | 367.28 | 638.41 | 3.00 | 3.67 |
| 69 | Watloo | 248 | 0.229 | 0.519 | 56.68 | 128.78 | 0.46 | 0.74 |
| 70 | Wes Park | 248 | 0.277 | 0.637 | 172.48 | 396.77 | 1.41 | 2.28 |
| 71 | Wingate Park | 92 | 0.004 | 0.214 | 0.344 | 19.73 | 0.003 | 0.11 |
| 72 | Wonderboom South | 227 | 0.582 | 0.940 | 132.01 | 213.59 | 1.08 | 1.22 |

Table 4.6 shows the suburb name, the total number (n) of Jacaranda trees in each suburb, the Mean Carbon (tonne) per tree, the Total Carbon (tonne) per suburb and the percentage of the Total Carbon for each suburb for 2004 and 2019. The data is reflected in *descending* order for 2004.

| No. | Suburb | n | Mean t C per tree | | Total t C per suburb | | % Total t C | |
|---|---|---|---|---|---|---|---|---|
| | | 2004/2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 1 | Asiatic Bazaar | 67 | 0.713 | 0.520 | 47.79 | 34.895 | 0.39 | 0.21 |
| 2 | Laudium | 281 | 0.680 | 0.702 | 191.18 | 197.340 | 1.56 | 1.22 |
| 3 | Claremont | 344 | 0.670 | 0.730 | 230.64 | 261.189 | 1.88 | 1.56 |
| 4 | Colbyn | 308 | 0.631 | 1.088 | 194.43 | 335.318 | 1.59 | 1.92 |
| 5 | Mountain View | 153 | 0.612 | 0.551 | 93.64 | 84.357 | 0.76 | 0.52 |
| 6 | Wonderboom South | 227 | 0.582 | 0.940 | 132.01 | 213.593 | 1.08 | 1.22 |
| 7 | Waterkloof | 1412 | 0.568 | 0.564 | 801.35 | 797.766 | 6.56 | 4.58 |
| 8 | Sinoville | 82 | 0.553 | 1.032 | 45.35 | 84.641 | 0.37 | 0.48 |
| 9 | Muckleneuk | 559 | 0.520 | 0.717 | 290.64 | 400.853 | 2.38 | 2.30 |
| 10 | Riviera | 465 | 0.516 | 1.273 | 239.76 | 591.952 | 1.96 | 3.40 |
| 11 | Pretoria Gardens | 132 | 0.511 | 0.462 | 67.44 | 61.00 | 0.55 | 0.35 |
| 12 | Lynnwood | 514 | 0.508 | 0.460 | 261.11 | 236.810 | 2.13 | 1.47 |
| 13 | Eloffsdal | 159 | 0.487 | 0.461 | 77.39 | 73.36 | 0.63 | 0.42 |
| 14 | Pretoria Central | 2853 | 0.483 | 0.483 | 1379.03 | 1380.68 | 11.29 | 7.94 |
| 15 | Brooklyn | 2535 | 0.472 | 0.413 | 1195.35 | 1048.534 | 9.79 | 6.52 |
| 16 | Rietondale | 454 | 0.467 | 1.226 | 211.94 | 556.730 | 1.73 | 3.20 |
| 17 | Salvokop | 87 | 0.462 | 0.267 | 40.15 | 23.257 | 0.32 | 0.14 |
| 18 | Rietfontein | 1028 | 0.460 | 0.569 | 473.02 | 584.970 | 3.87 | 3.36 |
| 19 | Menlo Park | 378 | 0.458 | 0.416 | 173.31 | 157.619 | 1.42 | 0.90 |
| 20 | Villiera | 1207 | 0.458 | 0.701 | 552.80 | 846.541 | 4.52 | 4.86 |
| 21 | Pretoria North | 840 | 0.443 | 0.569 | 372.49 | 478.673 | 3.05 | 2.75 |
| 22 | Sunnyside | 1836 | 0.430 | 0.394 | 788.65 | 724.217 | 6.46 | 4.50 |

| No. | Suburb | n | Mean t C per tree | | Total t C per suburb | | % Total t C | |
|---|---|---|---|---|---|---|---|---|
| | | 2004/2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 23 | Pretoria West | 702 | 0.424 | 0.276 | 297.84 | 193.884 | 2.44 | 1.20 |
| 24 | Lisdogan Park | 531 | 0.415 | 0.434 | 220.38 | 230.853 | 1.80 | 1.32 |
| 25 | Trevena | 128 | 0.415 | 0.559 | 53.11 | 71.597 | 0.43 | 0.41 |
| 26 | Nieuw Muckleneuk | 284 | 0.407 | 0.303 | 115.72 | 86.287 | 0.94 | 0.49 |
| 27 | Proclamation Hill | 896 | 0.393 | 0.565 | 352.15 | 506.955 | 2.88 | 2.91 |
| 28 | Hatfield | 977 | 0.385 | 0.555 | 375.98 | 542.57 | 3.08 | 0.74 |
| 29 | Arcadia | 1929 | 0.367 | 0.582 | 708.77 | 1124.469 | 5.80 | 4.46 |
| 30 | Annlin | 492 | 0.359 | 0.645 | 176.62 | 317.706 | 1.44 | 1.82 |
| 31 | Kwaggasrand | 310 | 0.352 | 0.675 | 109.05 | 209.251 | 0.89 | 1.20 |
| 32 | Valhalla | 447 | 0.348 | 0.455 | 155.68 | 203.395 | 1.27 | 1.26 |
| 33 | Silverton | 166 | 0.332 | 0.678 | 55.08 | 112.648 | 0.45 | 0.64 |
| 34 | Clydesdale | 67 | 0.317 | 0.389 | 21.26 | 26.123 | 0.17 | 0.16 |
| 35 | Pretoria Industrial | 396 | 0.297 | 0.434 | 117.62 | 230.835 | 0.96 | 1.32 |
| 36 | Wes Park | 622 | 0.277 | 0.637 | 172.48 | 396.773 | 1.41 | 2.28 |
| 37 | Danville | 67 | 0.269 | 0.601 | 18.05 | 40.28 | 0.14 | 0.23 |
| 38 | Ashlea Gardens | 409 | 0.263 | 0.309 | 107.49 | 126.559 | 0.88 | 0.78 |
| 39 | Eastwood | 499 | 0.259 | 0.208 | 129.20 | 129.20 | 1.05 | 0.59 |
| 40 | Queenswood | 215 | 0.253 | 0.228 | 54.31 | 49.099 | 0.44 | 0.28 |
| 41 | Lynwood Glen | 102 | 0.248 | 0.353 | 25.31 | 36.051 | 0.20 | 0.20 |
| 42 | Lukasrand | 323 | 0.248 | 0.347 | 80.04 | 112.397 | 0.65 | 0.64 |
| 43 | Waterkloof Ridge | 1509 | 0.243 | 0.423 | 367.28 | 638.415 | 3.00 | 3.67 |
| 44 | Watloo | 248 | 0.229 | 0.519 | 56.68 | 128.785 | 0.46 | 0.74 |
| 45 | Eersterust | 442 | 0.228 | 0.667 | 100.60 | 295.185 | 0.82 | 1.69 |
| 46 | Hillcrest | 155 | 0.218 | 0.360 | 33.85 | 55.926 | 0.27 | 0.32 |
| 47 | Meyers Park | 235 | 0.208 | 0.079 | 48.85 | 18.728 | 0.40 | 0.11 |
| 48 | La Montagne | 59 | 0.170 | 0.320 | 10.04 | 18.929 | 0.08 | 0.11 |

| No. | Suburb | n | Mean t C per tree | | Total t C per suburb | | % Total t C | |
|---|---|---|---|---|---|---|---|---|
| | | 2004/2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 49 | Alphen Park | 96 | 0.165 | 0.326 | 15.82 | 31.355 | 0.13 | 0.18 |
| 50 | Constantia Park | 393 | 0.131 | 0.258 | 51.38 | 101.64 | 0.42 | 0.58 |
| 51 | Waterkloof Park | 189 | 0.127 | 0.363 | 24.09 | 68.779 | 0.19 | 0.39 |
| 52 | Maroelana | 60 | 0.127 | 0.308 | 7.61 | 18.498 | 0.06 | 0.10 |
| 53 | Garsfontein | 449 | 0.122 | 0.209 | 54.67 | 93.901 | 0.44 | 0.58 |
| 54 | Kilner Park | 235 | 0.121 | 0.351 | 28.40 | 82.487 | 0.23 | 0.47 |
| 55 | Waterkloof Glen | 155 | 0.115 | 0.262 | 17.82 | 40.639 | 0.14 | 0.23 |
| 56 | Atteridgeville | 268 | 0.114 | 0.168 | 30.54 | 45.267 | 0.25 | 0.28 |
| 57 | Erasmusrand | 227 | 0.109 | 0.196 | 24.69 | 44.494 | 0.20 | 0.25 |
| 58 | Mamelodi | 304 | 0.094 | 0.335 | 28.54 | 101.968 | 0.23 | 0.58 |
| 59 | Jan Niemand Park | 61 | 0.088 | 0.207 | 5.37 | 12.648 | 0.04 | 0.07 |
| 60 | Hazelwood | 77 | 0.067 | 0.266 | 5.19 | 20.544 | 0.04 | 0.12 |
| 61 | Moreleta Park | 348 | 0.065 | 0.202 | 22.45 | 70.321 | 0.18 | 0.43 |
| 62 | Lynwood Ridge | 108 | 0.063 | 0.319 | 6.85 | 34.525 | 0.05 | 0.19 |
| 63 | Montana | 93 | 0.045 | 0.379 | 4.19 | 35.306 | 0.03 | 0.20 |
| 64 | Faerie Glen | 223 | 0.040 | 0.279 | 8.88 | 62.415 | 0.07 | 0.38 |
| 65 | Philip Nel Park | 56 | 0.039 | 0.287 | 2.18 | 16.093 | 0.01 | 0.09 |
| 66 | Mayville | 42 | 0.028 | 0.196 | 1.15 | 8.25 | 0.009 | 0.05 |
| 67 | Erasmuskloof | 70 | 0.023 | 0.230 | 1.62 | 16.117 | 0.01 | 0.10 |
| 68 | Saulsville | 208 | 0.014 | 0.167 | 2.90 | 34.807 | 0.02 | 0.21 |
| 69 | Elardus Park | 159 | 0.013 | 0.195 | 2.00 | 31.029 | 0.016 | 0.17 |
| 70 | Hestea Park | 103 | 0.009 | 0.729 | 0.91 | 75.11 | 0.007 | 0.46 |
| 71 | Newlands | 60 | 0.006 | 0.206 | 0.34 | 12.414 | 0.003 | 0.07 |
| 72 | Wingate Park | 92 | 0.004 | 0.169 | 0.34 | 15.575 | 0.003 | 0.09 |

Table 4.7 shows the suburb name, the total number (n) of Jacaranda trees in each suburb, the Mean Carbon (tonne) per tree, the Total Carbon (tonne) per suburb and the percentage of the Total Carbon for each suburb for 2004 and 2019. The data is reflected in *descending* order for 2019.

| | Suburb | n | Mean t C per tree | | Total t C per suburb | | % of Total t C | |
|---|---|---|---|---|---|---|---|---|
| | | 2004/2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 1. | Riviera | 465 | 0.516 | 1.273 | 239.76 | 591.95 | 1.96 | 3.40 |
| 2. | Rietondale | 454 | 0.467 | 1.226 | 211.94 | 556.730 | 1.73 | 3.20 |
| 3 | Colbyn | 308 | 0.631 | 1.088 | 194.43 | 335.318 | 1.59 | 1.92 |
| 4 | Sinoville | 82 | 0.553 | 1.032 | 45.35 | 84.641 | 0.37 | 0.48 |
| 5 | Wonderboom South | 227 | 0.582 | 0.940 | 132.01 | 213.593 | 1.08 | 1.22 |
| 6 | Claremont | 344 | 0.670 | 0.730 | 230.64 | 251.189 | 1.88 | 1.564 |
| 7 | Hestea Park | 103 | 0.009 | 0.729 | 0.913 | 75.11 | 0.007 | 0.46 |
| 8. | Muckleneuk | 559 | 0.520 | 0.717 | 290.64 | 400.853 | 2.38 | 2.30 |
| 9 | Laudium | 281 | 0.680 | 0.702 | 191.18 | 197.340 | 1.56 | 1.22 |
| 10. | Villiera | 1270 | 0.458 | 0.701 | 552.80 | 846.541 | 4.52 | 4.86 |
| 11. | Silverton | 166 | 0.332 | 0.678 | 55.08 | 112.648 | 0.45 | 0.64 |
| 12. | Kwaggasrand | 310 | 0.352 | 0.675 | 109.05 | 209.251 | 0.89 | 1.20 |
| 13. | Eersterust | 442 | 0.228 | 0.667 | 100.60 | 295.185 | 0.82 | 1.69 |
| 14. | Annlin | 492 | 0.359 | 0.645 | 176.62 | 317.706 | 1.44 | 1.82 |
| 15. | Wespark | 622 | 0.277 | 0.637 | 172.48 | 396.773 | 1.41 | 2.28 |
| 16. | Danville | 67 | 0.269 | 0.601 | 18.05 | 40.280 | 0.148 | 0.231 |
| 17. | Arcadia | 1929 | 0.367 | 0.582 | 708.77 | 1124.469 | 5.80 | 6.46 |
| 18. | Pretoria North | 840 | 0.443 | 0.569 | 372.49 | 478.673 | 3.05 | 2.75 |
| 19. | Rietfontein | 1028 | 0.460 | 0.569 | 473.02 | 584.970 | 3.87 | 3.36 |
| 20. | Proclamation Hill | 896 | 0.393 | 0.565 | 352.15 | 506.955 | 2.88 | 2.91 |
| 21. | Waterkloof | 1412 | 0.568 | 0.564 | 801.35 | 797.766 | 6.56 | 4.58 |
| 22. | Trevena | 128 | 0.415 | 0.559 | 53.11 | 71.597 | 0.43 | 0.411 |

| | Suburb | n | Mean t C per tree | | Total t C per suburb | | % of Total t C | |
|---|---|---|---|---|---|---|---|---|
| | | 2004/2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 23. | Hatfield | 977 | 0.385 | 0.555 | 375.98 | 542.57 | 3.08 | 3.12 |
| 24 | Mountain View | 153 | 0.612 | 0.551 | 93.64 | 84.357 | 0.76 | 0.525 |
| 25 | Asiatic Bazaar | 67 | 0.713 | 0.520 | 47.79 | 34.895 | 0.39 | 0.217 |
| 26. | Watloo | 248 | 0.229 | 0.519 | 56.68 | 128.785 | 0.46 | 0.740 |
| 27. | Pretoria Central | 2853 | 0.483 | 0.483 | 1379.03 | 1380.68 | 11.29 | 7.94 |
| 28. | Pretoria Gardens | 132 | 0.511 | 0.462 | 67.44 | 61.00 | 0.55 | 0.35 |
| 29. | Eloffsdal | 159 | 0.487 | 0.461 | 77.39 | 73.36 | 0.63 | 0.422 |
| 30 | Lynnwood | 514 | 0.508 | 0.460 | 252.930 | 236.810 | 2.13 | 1.1.474 |
| 31 | Vahalla | 447 | 0.348 | 0.455 | 155.68 | 203.395 | 1.27 | 1.266 |
| 32. | Pretoria Industrial | 396 | 0.297 | 0.442 | 117.62 | 175.172 | 0.96 | 1.00 |
| 33. | Lisdogan Park | 531 | 0.415 | 0.434 | 220.38 | 230.835 | 1.80 | 1.32 |
| 34. | Waterkloof Ridge | 1509 | 0.243 | 0.423 | 367.28 | 638.415 | 3.00 | 3.672 |
| 35. | Menlo Park | 378 | 0.458 | 0.416 | 173.31 | 157.619 | 1.42 | 0.906 |
| 36 | Brooklyn | 2535 | 0.472 | 0.413 | 1195.35 | 1048.534 | 9.79 | 6.528 |
| 37 | Sunnyside | 1836 | 0.430 | 0.394 | 788.65 | 724.217 | 6.46 | 4.509 |
| 38 | Clydesdale | 67 | 0.317 | 0.389 | 21.26 | 26.123 | 0.17 | 0.162 |
| 39. | Montana | 93 | 0.045 | 0.379 | 4.19 | 35.306 | 0.034 | 0.203 |
| 40. | Waterkloof Park | 189 | 0.127 | 0.363 | 24.09 | 68.779 | 0.197 | 0.395 |
| 41. | Hillcrest | 155 | 0.218 | 0.360 | 33.85 | 55.926 | 0.27 | 0.321 |
| 42. | Lynnwood Glen | 102 | 0.248 | 0.353 | 25.31 | 36.051 | 0.20 | 0.207 |
| 43. | Kilner Park | 235 | 0.121 | 0.351 | 28.40 | 82.487 | 0.23 | 0.474 |
| 44. | Lukasrand | 323 | 0.248 | 0.347 | 80.04 | 112.397 | 0.65 | 0.646 |
| 45. | Mamelodi | 304 | 0.094 | 0.335 | 28.54 | 101.968 | 0.23 | 0.586 |
| 46. | Alphen Park | 96 | 0.165 | 0.326 | 15.82 | 31.355 | 0.13 | 0.180 |
| 47 | La Montagne | 59 | 0.170 | 0.320 | 10.04 | 18.929 | 0.08 | 0.117 |
| 48. | Lynnwood Ridge | 108 | 0.063 | 0.319 | 6.85 | 34.525 | 0.056 | 0.198 |
| 49 | Ashlea Gardens | 409 | 0.263 | 0.309 | 107.49. | 126.559 | 0.88 | 0.788 |

| | Suburb | n | Mean t C per tree | | Total t C per suburb | | % of Total t C | |
|---|---|---|---|---|---|---|---|---|
| | | 2004/2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 50. | Maroelana | 60 | 0.127 | 0.308 | 7.61 | 18.498 | 0.06 | 0.106 |
| 51. | Nieuw Muckleneuk | 284 | 0.407 | 0.303 | 115.72 | 86.287 | 0.94 | 0.496 |
| 52. | Philip Nel Park | 56 | 0.039 | 0.287 | 2.18 | 16.093 | 0.01 | 0.092 |
| 53 | Faerie Glen | 223 | 0.040 | 0.279 | 8.88 | 62.415 | 0.073 | 0.388 |
| 54 | Pretoria West | 702 | 0.424 | 0.276 | 297.84 | 193.884 | 2.44 | 1.207 |
| 55 | Salvokop | 87 | 0.462 | 0.267 | 40.15 | 23.257 | 0.32 | 0.144 |
| 56 | Hazelwood | 77 | 0.067 | 0.266 | 5.197 | 20.544 | 0.04 | 0.127 |
| 57. | Waterkloof Glen | 155 | 0.115 | 0.262 | 17.82 | 40.639 | 0.146 | 0.233 |
| 58. | Constantia Park | 393 | 0.131 | 0.258 | 51.38 | 101.641 | 0.42 | 0.584 |
| 59 | Erasmuskloof | 70 | 0.023 | 0.230 | 1.65 | 16.117 | 0.01 | 0.100 |
| 60. | Queenswood | 215 | 0.253 | 0.228 | 54.31 | 49.099 | 0.44 | 0.282 |
| 61 | Garsfontein | 449 | 0.122 | 0.209 | 54.67 | 93.901 | 0.44 | 0.584 |
| 62. | Eastwood | 499 | 0.259 | 0.208 | 104.13 | 129.20 | 1.5 | 0.599 |
| 63 | Jan Niemand Park | 61 | 0.088 | 0.207 | 5.37 | 12.648 | 0.04 | 0.078 |
| 64 | Newlands | 60 | 0.006 | 0.206 | 0.346 | 12.414 | 0.003 | 0.077 |
| 65 | Moreleta Park | 348 | 0.065 | 0.202 | 22.45 | 70.321 | 0.18 | 0.0.437 |
| 66. | Erasmusrand | 227 | 0.109 | 0.196 | 24.69 | 44.494 | 0.202 | 0.255 |
| 67 | Mayville | 42 | 0.028 | 0.196 | 1.15 | 8.25 | 0.009 | 0.051 |
| 68. | Elardus Park | 159 | 0.013 | 0.195 | 2.00 | 31.029 | 0.016 | 0.178 |
| 69 | Wingate Park | 92 | 0.004 | 0.169 | 0.344 | 15.575 | 0.003 | 0.096 |
| 70 | Attridgeville | 268 | 0.114 | 0.168 | 30.54 | 45.267 | 0.25 | 0.281 |
| 71 | Saulsville | 208 | 0.014 | 0.167 | 2.90 | 34.807 | 0.02 | 0.216 |
| 72. | Meyers Park | 235 | 0.208 | 0.079 | 48.85 | 18.728 | 0.400 | 0.116 |

### 4.2.3. Mean Carbon Dioxide equivalents and the associated monetary values

Table 4.8 shows the Mean Carbon and the Mean Carbon Dioxide equivalent ($CO_2$ eq) and the associated US$ Dollar and Rand values. This study used the South African National Treasury's Carbon Tax Bill which states that 1 tonne of Carbon is equal to R120. This study used the exchange rate, relevant to the time of study, of US$1 being equal to R15.00 (businesstech.co.za, 2018). Therefore, to calculate the US$ value the Carbon Tax Rand value was divided by the exchange rate value above of US$1 Is equal to R15.

Table 4.9 shows the Mean Carbon, Carbon Dioxide Equivalent and the associated Carbon Dioxide Equivalent US Dollar and Rand values in descending order for the baseline study. The highest mean carbon dioxide equivalent in the baseline study occurred in Asiatic Bazaar, Laudium, Claremont and Colbyn. The estimated combined above ground and below ground $CO_2$ eq was 2.618 t $CO_2$ eq, 2.497 t $CO_2$ eq, 2.461 t $CO_2$ eq and 2.317 t $CO_2$ eq respectively with an estimated Carbon Tax Rand value of R172.51, R164.55, R162.16 and R152.68, respectively. The lowest mean carbon dioxide equivalent values in the baseline study occurred in Elardus Park, Hestea Park, Newlands and Wingate Park. The estimated combined above ground and below ground $CO_2$ eq was 0.046 t $CO_2$ eq, 0.033 t $CO_2$ eq, 0.021 t $CO_2$ eq and 0.014 t $CO_2$ eq with an estimated Carbon Tax Rand value of R3.05, R2.14, R1.40 and R0.90, respectively.

Table 4.10 shows the Mean Carbon, the Mean $CO_2$ eq and the associated Dollar and Rand values in descending order for this study. In this study the highest mean $CO_2$ eq occurred in Riviera, Rietondale, Colbyn and Sinoville. The estimated combined above ground and below ground $CO_2$ eq was 4.67 t $CO_2$ eq, 4.50 t $CO_2$, 4.13 t $CO_2$ eq and 3.99 t $CO_2$ eq respectively with an estimated Carbon Tax Rand value of R560.63, R540.05, R479.46 and R454.58, respectively. The lowest mean carbon dioxide equivalent values in this study were Elardus Park, Atteridgeville, Saulsville and Meyers Park. The estimate combined above ground and below ground Carbon Dioxide Equivalent values were 0.716 t $CO_2$ eq, 0.619 t $CO_2$ eq, 0.614 t $CO_2$ eq and 0.292 t $CO_2$ eq with an estimated Carbon Tax Rand value of R85.94, R74.39, R73.70 and R35.10, respectively.

Figure 4.5 illustrates the mean $CO_2$ eq per suburb in 2019 with the highest quantities shown with the darkest colour. Figure 4.6 compares the mean $CO_2$ eq in 2004 and 2019. Figure 4.7 illustrates the mean $CO_2$ eq rand values in 2019 with the highest values shown with the darkest colour. Figure 4.8 compares the mean $CO_2$ eq Carbon Tax Rand values from 2004 and 2019. Figure 4.9 illustrates the mean $CO_2$ eq dollar values in 2019 with highest values shown with the darkest colour. Figure 4.10 compares the mean $CO_2$ eq dollar values from 2004 and 2019. Negative values represent a net reduction in the mean Carbon Dioxide Equivalent values and the corresponding monetary values since 2004. The positive values represent a net increase in the mean Carbon Dioxide Equivalent values and the corresponding monetary values since 2004.

Table 4.8 shows the suburb name, the Mean Carbon (tonne) per tree, the Mean Carbon Dioxide Equivalent (tonne) per tree as well the associated Mean Carbon Dioxide equivalent US Dollar and Rand values in *alphabetical* order.

| | **Suburb** | **Mean t C per tree** | | **Mean t $CO_2$eq per tree** | | **US$** | | **ZAR** | |
|---|---|---|---|---|---|---|---|---|---|
| | | **2004** | **2019** | **2004** | **2019** | **2004** | **2019** | **2004** | **2019** |
| 1. | Alphen Park | 0.165 | 0.326 | 0.605 | 1.198 | 6.05 | 9.59 | 39.86 | 143.84 |
| 2. | Annlin | 0.359 | 0.645 | 1.318 | 2.369 | 13.18 | 18.96 | 86.82 | 284.38 |
| 3. | Arcadia | 0.367 | 0.582 | 1.348 | 2.139 | 13.48 | 17.11 | 88.86 | 256.72 |
| 4. | Asiatic Bazaar | 0.713 | 0.520 | 2.618 | 1.911 | 26.18 | 15.29 | 172.51 | 229.37 |
| 5. | Ashlea Gardens | 0.263 | 0.309 | 0.965 | 1.135 | 9.65 | 9.09 | 63.56 | 136.28 |
| 6. | Atteridgeville | 0.114 | 0.168 | 0.418 | 0.619 | 4.18 | 4.96 | 27.56 | 74.39 |
| 7. | Brooklyn | 0.472 | 0.413 | 1.731 | 1.517 | 17.31 | 12.14 | 114.04 | 182.16 |
| 8. | Claremont | 0.670 | 0.730 | 2.461 | 2.679 | 24.61 | 21.44 | 162.16 | 321.58 |
| 9. | Clydesdale | 0.317 | 0.389 | 1.165 | 1.430 | 11.65 | 11.45 | 76.76 | 171.72 |
| 10. | Colbyn | 0.631 | 1.088 | 2.317 | 3.995 | 23.17 | 31.96 | 152.68 | 479.46 |
| 11. | Constantia Park | 0.131 | 0.258 | 0.48 | 0.949 | 4.8 | 7.59 | 31.62 | 113.90 |
| 12. | Danville | 0.269 | 0.601 | 0.989 | 2.206 | 9.89 | 17.65 | 65.16 | 264.77 |
| 13. | Eastwood | 0.259 | 0.208 | 0.95 | 0.765 | 9.5 | 6.13 | 62.62 | 91.90 |
| 14. | Eersterust | 0.228 | 0.667 | 0.835 | 2.450 | 8.35 | 19.61 | 55.05 | 294.11 |
| 15. | Elardus Park | 0.013 | 0.461 | 0.046 | 1.693 | 0.46 | 13.55 | 3.05 | 203.53 |
| 16. | Eloffsdal | 0.487 | 0.195 | 1.786 | 0.716 | 17.86 | 5.73 | 117.73 | 85.94 |
| 17. | Erasmusrand | 0.109 | 0.196 | 0.399 | 0.719 | 3.99 | 5.75 | 26.31 | 86.32 |
| 18. | Erasmuskloof | 0.023 | 0.230 | 0.085 | 0.845 | 0.85 | 6.76 | 5.61 | 101.40 |
| 19. | Faerie Glen | 0.040 | 0.279 | 0.146 | 1.02 | 1.46 | 8.22 | 9.64 | 123.26 |
| 20. | Garsfontein | 0.122 | 0.209 | 0.447 | 0.767 | 4.47 | 6.14 | 29.45 | 92.10 |
| 21. | Hatfield | 0.385 | 0.555 | 1.412 | 2.038 | 14.12 | 16.30 | 93.07 | 244.57 |
| 22. | Hazelwood | 0.067 | 0.266 | 0.248 | 0.614 | 2.48 | 4.91 | 16.32 | 73.70 |
| 23. | Hestea Park | 0.009 | 0.729 | 0.033 | 2.676 | 0.33 | 21.41 | 2.14 | 321.17 |

| | Suburb | Mean t C per tree | | Mean t $CO_2$eq per tree | | US$ | | ZAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 24. | Hillcrest | 0.218 | 0.360 | 0.802 | 1.324 | 8.02 | 10.59 | 52.83 | 158.90 |
| 25. | Jan Niemand Park | 0.088 | 0.207 | 0.323 | 0.760 | 3.23 | 6.09 | 21.31 | 91.32 |
| 26. | Kilner Park | 0.121 | 0.351 | 0.444 | 1.288 | 4.44 | 10.31 | 29.23 | 154.58 |
| 27. | Kwaggasrand | 0.352 | 0.675 | 1.291 | 2.477 | 12.91 | 19.82 | 85.08 | 297.27 |
| 28. | La Montagne | 0.170 | 0.320 | 0.625 | 1.177 | 6.25 | 9.42 | 41.19 | 141.29 |
| 29. | Laudium | 0.680 | 0.702 | 2.497 | 2.577 | 24.97 | 20.62 | 164.55 | 309.28 |
| 30. | Lisdogan Park | 0.415 | 0.434 | 1.523 | 1.595 | 15.23 | 12.76 | 100.38 | 191.45 |
| 31. | Lukasrand | 0.248 | 0.347 | 0.909 | 1.277 | 9.09 | 10.22 | 59.93 | 153.25 |
| 32. | Lynnwood | 0.508 | 0.460 | 1.864 | 1.690 | 18.64 | 13.53 | 122.86 | 202.90 |
| 33. | Lynnwood Glen | 0.248 | 0.353 | 0.911 | 1.297 | 9.11 | 10.38 | 60.02 | 155.65 |
| 34. | Lynnwood Ridge | 0.063 | 0.319 | 0.233 | 1.173 | 2.33 | 9.39 | 15.35 | 140.78 |
| 35. | Mamelodi | 0.094 | 0.335 | 0.345 | 1.231 | 3.45 | 9.85 | 22.71 | 147.72 |
| 36. | Maroelana | 0.127 | 0.308 | 0.466 | 1.131 | 4.66 | 9.05 | 30.71 | 135.77 |
| 37. | Mayville | 0.028 | 0.196 | 0.101 | 0.720 | 1.01 | 5.77 | 6.60 | 86.51 |
| 38. | Menlo Park | 0.458 | 0.416 | 1.683 | 1.530 | 16.83 | 12.24 | 110.89 | 183.63 |
| 39. | Meyers Park | 0.208 | 0.079 | 0.763 | 0.292 | 7.63 | 2.34 | 50.28 | 35.10 |
| 40. | Montana | 0.045 | 0.379 | 0.166 | 1.393 | 1.66 | 11.15 | 10.91 | 167.19 |
| 41. | Moreleta Park | 0.065 | 0.202 | 0.237 | 0.741 | 2.37 | 5.93 | 15.60 | 88.99 |
| 42. | Mountain View | 0.612 | 0.551 | 2.246 | 2.023 | 22.46 | 16.19 | 148.03 | 242.82 |
| 43. | Muckleneuk | 0.520 | 0.717 | 1.908 | 2.631 | 19.08 | 21.05 | 125.75 | 3.15.80 |
| 44. | Newlands | 0.006 | 0.206 | 0.021 | 0.759 | 0.21 | 6.07 | 1.40 | 91.12 |
| 45. | Nieuw Muckleneuk | 0.407 | 0.303 | 1.495 | 1.115 | 14.95 | 8.92 | 98.55 | 133.80 |
| 46. | Philip Nel Park | 0.039 | 0.287 | 0.143 | 1.054 | 1.43 | 8.44 | 9.42 | 126.56 |
| 47. | Pretoria Central | 0.483 | 0.483 | 1.774 | 1.776 | 17.74 | 14.21 | 116.90 | 231.12 |
| 48. | Pretoria Gardens | 0.511 | 0.462 | 1.875 | 1.696 | 18.75 | 13.57 | 123.57 | 203.21 |
| 49. | Pretoria Industrial | 0.297 | 0.442 | 1.09 | 1.623 | 10.90 | 12.99 | 71.84 | 194.81 |

| | Suburb | Mean t C per tree | | Mean t $CO_2$eq per tree | | US$ | | ZAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 50. | Pretoria North | 0.443 | 0.569 | 1.627 | 2.091 | 16.27 | 16.73 | 107.25 | 250.96 |
| 51. | Pretoria West | 0.424 | 0.276 | 1.557 | 1.013 | 15.57 | 8.11 | 102.61 | 121.63 |
| 52. | Proclamation Hill | 0.393 | 0.565 | 1.442 | 2.076 | 14.42 | 16.61 | 95.06 | 249.17 |
| 53. | Queenswood | 0.253 | 0.228 | 0.927 | 0.838 | 9.27 | 6.70 | 61.10 | 100.57 |
| 54. | Rietfontein | 0.460 | 0.569 | 1.689 | 2.088 | 16.89 | 16.71 | 111.29 | 250.60 |
| 55. | Rietondale | 0.467 | 1.226 | 1.713 | 4.500 | 17.13 | 36.00 | 112.90 | 540.05 |
| 56. | Riviera | 0.516 | 1.273 | 1.892 | 4.671 | 18.92 | 37.88 | 124.70 | 560.63 |
| 57. | Saulsville | 0.014 | 0.167 | 0.051 | 0.614 | 0.51 | 4.91 | 3.37 | 73.70 |
| 58. | Salvokop | 0.462 | 0.267 | 1.694 | 0.981 | 16.94 | 7.85 | 111.64 | 117.73 |
| 59. | Silverton | 0.332 | 0.678 | 1.218 | 2.490 | 12.18 | 19.92 | 80.25 | 298.85 |
| 60. | Sinoville | 0.553 | 1.032 | 2.03 | 3.788 | 20.30 | 30.31 | 133.78 | 454.58 |
| 61. | Sunnyside | 0.430 | 0.394 | 1.576 | 1.447 | 15.76 | 11.58 | 103.89 | 173.72 |
| 62. | Trevena | 0.415 | 0.559 | 1.523 | 2.052 | 15.23 | 16.42 | 100.35 | 246.33 |
| 63. | Valhalla | 0.348 | 0.455 | 1.278 | 1.669 | 12.78 | 13.35 | 84.23 | 200.39 |
| 64. | Villiera | 0.458 | 0.701 | 1.681 | 2.573 | 16.81 | 20.59 | 110.77 | 308.87 |
| 65. | Waterkloof | 0.568 | 0.564 | 2.083 | 2.073 | 20.83 | 16.59 | 137.26 | 248.82 |
| 66. | Waterkloof Glen | 0.115 | 0.262 | 0.422 | 0.962 | 4.22 | 7.70 | 27.81 | 115.46 |
| 67. | Waterkloof Park | 0.127 | 0.363 | 0.468 | 1.335 | 4.68 | 10.68 | 30.83 | 160.26 |
| 68. | Waterkloof Ridge | 0.243 | 0.423 | 0.893 | 1.552 | 8.93 | 12.42 | 58.87 | 186.32 |
| 69. | Wespark | 0.277 | 0.637 | 1.018 | 2.341 | 10.18 | 18.73 | 67.07 | 280.93 |
| 70. | Watloo | 0.229 | 0.519 | 0.839 | 1.905 | 8.39 | 15.25 | 55.28 | 228.69 |
| 71. | Wingate Park | 0.004 | 0.169 | 0.014 | 0.621 | 0.14 | 4.97 | 0.90 | 74.56 |
| 72. | Wonderboom South | 0.582 | 0.940 | 2.134 | 3.453 | 21.34 | 27.63 | 140.65 | 414.38 |

Table 4.9 shows the suburb name, the Mean Carbon (tonne) per tree, the Mean Carbon Dioxide Equivalent (tonne) per tree as well the associated Mean Carbon Dioxide US Dollar and Rand values. The data is reflected in *descending* order for 2004.

| | Suburb | Mean t C per tree | | Mean t $CO_2$eq per tree | | US$ | | ZAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 1. | Asiatic Bazaar | 0.713 | 0.520 | 2.618 | 1.911 | 26.18 | 15.29 | 172.51 | 229.37 |
| 2. | Laudium | 0.680 | 0.702 | 2.497 | 2.577 | 24.97 | 20.62 | 164.55 | 309.28 |
| 3. | Claremont | 0.670 | 0.730 | 2.461 | 2.679 | 24.61 | 21.44 | 162.16 | 321.58 |
| 4. | Colbyn | 0.631 | 1.088 | 2.317 | 3.995 | 23.17 | 31.96 | 152.68 | 479.46 |
| 5. | Mountain View | 0.612 | 0.551 | 2.143 | 2.023 | 22.46 | 16.19 | 148.03 | 242.82 |
| 6. | Wonderboom South | 0.582 | 0.940 | 2.134 | 3.453 | 21.34 | 27.63 | 140.65 | 414.38 |
| 7. | Waterkloof | 0.568 | 0.564 | 2.083 | 2.073 | 20.83 | 16.59 | 137.26 | 248.82 |
| 8. | Sinoville | 0.553 | 1.032 | 2.030 | 3.788 | 20.30 | 30.31 | 133.78 | 454.58 |
| 9. | Muckleneuk | 0.520 | 0.717 | 1.908 | 2.631 | 19.08 | 21.05 | 125.75 | 315.80 |
| 10. | Riviera | 0.516 | 1.273 | 1.892 | 4.671 | 18.92 | 37.88 | 124.70 | 560.63 |
| 11. | Pretoria Gardens | 0.511 | 0.462 | 1.875 | 1.696 | 18.75 | 13.57 | 123.57 | 203.21 |
| 12. | Lynnwood | 0.508 | 0.460 | 1.864 | 1.690 | 18.64 | 13.53 | 122.86 | 202.90 |
| 13. | Eloffsdal | 0.487 | 0.461 | 1.786 | 1.693 | 17.86 | 13.55 | 117.73 | 203.53 |
| 14. | Pretoria Central | 0.483 | 0.483 | 1.774 | 1.776 | 17.74 | 14.21 | 116.90 | 213.12 |
| 15. | Brooklyn | 0.472 | 0.413 | 1.731 | 1.517 | 17.31 | 12.14 | 114.04 | 182.16 |
| 16. | Rietondale | 0.467 | 1.226 | 1.713 | 4.500 | 17.13 | 36.00 | 112.90 | 540.05 |
| 17. | Salvokop | 0.462 | 0.267 | 1.694 | 0.981 | 16.94 | 7.85 | 111.64 | 117.73 |
| 18. | Rietfontein | 0.460 | 0.569 | 1.689 | 2.088 | 16.89 | 16.71 | 111.29 | 250.60 |
| 19. | Menlo Park | 0.458 | 0.416 | 1.683 | 1.530 | 16.83 | 12.24 | 110.89 | 183.63 |
| 20. | Villiera | 0.458 | 0.701 | 1.681 | 2.573 | 16.81 | 20.59 | 110.77 | 308.87 |
| 21. | Pretoria North | 0.443 | 0.569 | 1.627 | 2.091 | 16.27 | 16.73 | 107.25 | 250.96 |
| 22. | Sunnyside | 0.430 | 0.394 | 1.576 | 1.447 | 15.76 | 11.58 | 103.89 | 173.72 |
| 23. | Pretoria West | 0.424 | 0.276 | 1.557 | 1.013 | 15.57 | 8.11 | 102.61 | 121.63 |

| | Suburb | Mean t C per tree | | Mean t $CO_2$eq per tree | | US$ | | ZAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 24. | Lisdogan Park | 0.415 | 0.434 | 1.523 | 1.595 | 15.23 | 12.76 | 100.38 | 191.45 |
| 25. | Trevena | 0.415 | 0.559 | 1.523 | 2.052 | 15.23 | 16.42 | 1000.35 | 246.33 |
| 26. | Niew Muckleneuk | 0.407 | 0.303 | 1.495 | 1.115 | 14.95 | 8.92 | 98.55 | 133.80 |
| 27. | Proclamation Hill | 0.393 | 0.565 | 1.442 | 2.076 | 14.42 | 16.61 | 95.06 | 249.17 |
| 28. | Hatfield | 0.385 | 0.555 | 1.412 | 2.038 | 14.12 | 16.30 | 93.07 | 244.57 |
| 29. | Arcadia | 0.367 | 0.582 | 1.348 | 2.139 | 13.48 | 17.11 | 88.86 | 256.72 |
| 30. | Annlin | 0.359 | 0.645 | 1.318 | 2.369 | 13.18 | 18.96 | 86.82 | 284.38 |
| 31. | Kwaggasrand | 0.352 | 0.675 | 1.291 | 2.477 | 12.91 | 19.82 | 85.08 | 297.27 |
| 32. | Valhalla | 0.348 | 0.455 | 1.278 | 1.669 | 12.78 | 3.36 | 84.23 | 200.39 |
| 33. | Silverton | 0.332 | 0.678 | 1.218 | 2.490 | 12.18 | 19.92 | 80.25 | 298.85 |
| 34. | Clydesdale | 0.317 | 0.389 | 1.165 | 1.430 | 11.65 | 11.45 | 76.76 | 171.72 |
| 35. | Pretoria Industrial | 0.297 | 0.442 | 1.090 | 1.623 | 10.90 | 12.99 | 71.84 | 194.81 |
| 36. | Wes Park | 0.277 | 0.637 | 1.018 | 2.341 | 10.18 | 18.73 | 67.07 | 280.93 |
| 37. | Danville | 0.269 | 0.601 | 0.989 | 2.206 | 9.89 | 17.65 | 65.15 | 264.77 |
| 38. | Ashlea Gardens | 0.263 | 0.309 | 0.965 | 1.135 | 9.65 | 9.09 | 63.55 | 136.28 |
| 39. | Eastwood | 0.259 | 0.208 | 0.950 | 0.765 | 9.50 | 6.13 | 62.62 | 91.90 |
| 40. | Queenswood | 0.253 | 0.228 | 0.927 | 0.838 | 9.27 | 6.70 | 61.10 | 100.57 |
| 41. | Lynnwood Glen | 0.248 | 0.353 | 0.911 | 1.297 | 9.11 | 10.38 | 60.02 | 155.56 |
| 42. | Lukasrand | 0.248 | 0.347 | 0.909 | 1.277 | 9.09 | 10.22 | 59.93 | 153.25 |
| 43. | Waterkloof Ridge | 0.243 | 0.423 | 0.893 | 1.552 | 8.93 | 12.42 | 58.87 | 186.32 |
| 44. | Watloo | 0.229 | 0.519 | 0.839 | 1.905 | 8.39 | 15.25 | 55.28 | 228.69 |
| 45. | Eersterust | 0.228 | 0.667 | 0.835 | 2.450 | 8.35 | 19.61 | 55.05 | 294.11 |
| 46. | Hilcrest | 0.218 | 0.360 | 0.802 | 1.324 | 8.02 | 10.59 | 52.83 | 158.90 |
| 47. | Meyers Park | 0.208 | 0.079 | 0.763 | 0.292 | 7.63 | 2.34 | 50.28 | 35.10 |
| 48. | La Montagne | 0.170 | 0.320 | 0.625 | 1.177 | 6.25 | 9.42 | 41.19 | 141.29 |
| 49. | Alphen Park | 0.165 | 0.326 | 0.605 | 1.198 | 6.05 | 9.59 | 39.86 | 143.84 |

| | Suburb | Mean t C per tree | | Mean t $CO_2$eq per tree | | US$ | | ZAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 50. | Constantia Park | 0.131 | 0.258 | 0.480 | 0.949 | 4.80 | 7.59 | 31.62 | 113.90 |
| 51. | Waterkloof Park | 0.127 | 0.363 | 0.468 | 1.335 | 4.68 | 10.68 | 30.83 | 160.26 |
| 52. | Maroelana | 0.127 | 0.308 | 0.466 | 1.131 | 4.66 | 9.05 | 30.71 | 135.77 |
| 53. | Garsfontein | 0.122 | 0.209 | 0.447 | 0.767 | 4.47 | 6.14 | 29.45 | 92.10 |
| 54. | Kilner Park | 0.121 | 0.351 | 0.444 | 1.288 | 4.44 | 10.31 | 29.23 | 154.58 |
| 55. | Waterkloof Glen | 0.115 | 0.262 | 0.422 | 0.962 | 4.22 | 7.70 | 27.81 | 115.46 |
| 56. | Attridgeville | 0.114 | 0.168 | 0.418 | 0.619 | 4.18 | 4.96 | 27.56 | 74.39 |
| 57. | Erasmusrand | 0.109 | 0.196 | 0.399 | 0.719 | 3.99 | 5.75 | 26.31 | 86.32 |
| 58. | Mamelodi | 0.094 | 0.335 | 0.345 | 1.231 | 3.45 | 9.85 | 22.71 | 147.72 |
| 59. | Jan Niemand Park | 0.088 | 0.207 | 0.323 | 0.760 | 3.23 | 6.09 | 21.31 | 91.32 |
| 60. | Hazelwood | 0.067 | 0.266 | 0.248 | 0.979 | 2.48 | 7.83 | 16.32 | 117.50 |
| 61. | Moreleta Park | 0.065 | 0.202 | 0.237 | 0.741 | 2.37 | 5.93 | 15.60 | 88.99 |
| 62. | Lynnwood Ridge | 0.063 | 0.319 | 0.233 | 1.173 | 2.33 | 9.39 | 15.36 | 140.78 |
| 63. | Montana | 0.045 | 0.379 | 0.166 | 1.393 | 1.66 | 11.15 | 15.91 | 167.19 |
| 64. | Faerie Glen | 0.040 | 0.279 | 0.146 | 1.02 | 1.46 | 8.22 | 9.64 | 123.26 |
| 65. | Philip Nel Pak | 0.039 | 0.287 | 0.143 | 1.054 | 1.43 | 8.44 | 9.42 | 126.56 |
| 66. | Mayville | 0.028 | 0.196 | 0.101 | 0.720 | 1.01 | 5.77 | 6.60 | 86.51 |
| 67. | Erasmuskloof | 0.023 | 0.230 | 0.085 | 0.845 | 0.85 | 6.76 | 5.61 | 101.40 |
| 68. | Saulsville | 0.014 | 0.167 | 0.051 | 0.614 | 0.51 | 4.91 | 3.37 | 73.70 |
| 69. | Elardus Park | 0.013 | 0.195 | 0.046 | 0.716 | 0.46 | 5.73 | 3.05 | 85.94 |
| 70. | Hestea Park | 0.009 | 0.729 | 0.033 | 2.676 | 0.33 | 21.41 | 2.14 | 321.17 |
| 71. | Newlands | 0.006 | 0.206 | 0.021 | 0.759 | 0.21 | 6.07 | 1.40 | 91.12 |
| 72. | Wingate Park | 0.004 | 0.169 | 0.014 | 0.621 | 0.14 | 4.97 | 0.90 | 74.56 |

Table 4.10: lists the suburb name, the Mean tonne Carbon (tonne) per tree, the Mean Carbon Dioxide Equivalent (tonne) per tree as well the associated Mean Carbon Dioxide US Dollar and Rand values. The data is reflected in *descending* order 2019.

| | Suburb | Mean t C per tree | | Mean t $CO_2$ per tree | | US$ | | ZAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 1. | Riviera | 0.516 | 1.273 | 1.892 | 4.671 | 18.92 | 37.88 | 124.70 | 560.63 |
| 2. | Rietondale | 0.467 | 1.226 | 1.713 | 4.500 | 17.13 | 36.00 | 112.90 | 540.05 |
| 3 | Colbyn | 0.631 | 1.088 | 2.317 | 3.995 | 23.17 | 31.96 | 154.68 | 479.46 |
| 4. | Sinoville | 0.553 | 1.032 | 2.03 | 3.788 | 20.3 | 30.31 | 133.78 | 454.58 |
| 5. | Wonderboom South | 0.582 | 0.940 | 2.134 | 3.453 | 21.34 | 27.63 | 140.65 | 414.38 |
| 6. | Claremont | 0.670 | 0.730 | 2.461 | 2.679 | 24.61 | 21.44 | 162.16 | 321.56 |
| 7. | Hestea Park | 0.009 | 0.729 | 0.033 | 2.676 | 0.33 | 21.41 | 2.14 | 321.17 |
| 8. | Mucklenuek | 0.520 | 0.717 | 1.908 | 2.631 | 19.08 | 21.05 | 125.75 | 315.80 |
| 9. | Laudium | 0.680 | 0.702 | 2.497 | 2.577 | 24.97 | 20.62 | 164.55 | 309.28 |
| 10. | Villiera | 0.458 | 0.701 | 1.681 | 2.573 | 16.81 | 20.59 | 110.77 | 308.87 |
| 11. | Silverton | 0.332 | 0.678 | 1.218 | 2.490 | 12.18 | 19.92 | 80.25 | 298.85 |
| 12. | Kwaggasrand | 0.352 | 0.675 | 1.291 | 2.477 | 12.91 | 19.82 | 85.08 | 297.27 |
| 13. | Eersterust | 0.228 | 0.667 | 0.835 | 2.450 | 8.35 | 19.61 | 55.05 | 294.11 |
| 14. | Annlin | 0.359 | 0.645 | 1.318 | 2.369 | 13.18 | 18.96 | 86.82 | 284.38 |
| 15. | Wespark | 0.277 | 0.637 | 1.018 | 2.341 | 10.18 | 18.73 | 67.07 | 280.93 |
| 16. | Danville | 0.269 | 0.601 | 0.989 | 2.206 | 9.89 | 17.65 | 65.15 | 264.77 |
| 17. | Arcadia | 0.367 | 0.582 | 1.348 | 2.139 | 13.48 | 17.11 | 88.86 | 256.72 |
| 18. | Pretoria North | 0.443 | 0.569 | 1.627 | 2.091 | 16.27 | 16.73 | 107.25 | 250.96 |
| 19. | Rietfontein | 0.460 | 0.569 | 1.689 | 2.088 | 16.89 | 16.71 | 111.29 | 250.60 |
| 20. | Proclamation Hill | 0.393 | 0.565 | 1.442 | 2.076 | 14.42 | 16.61 | 95.06 | 249.17 |
| 21. | Waterkloof | 0.568 | 0.564 | 2.083 | 2.073 | 20.83 | 16.59 | 137.26 | 248.82 |
| 22. | Trevena | 0.415 | 0.559 | 1.523 | 2.052 | 15.23 | 16.42 | 100.35 | 246.33 |
| 23. | Hatfield | 0.385 | 0.555 | 1.412 | 2.038 | 14.12 | 16.30 | 93.07 | 244.57 |

| | Suburb | Mean t C per tree | | Mean t $CO_2$ per tree | | US$ | | ZAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 24. | Mountain View | 0.612 | 0.551 | 2.246 | 2.023 | 22.46 | 16.19 | 148.03 | 242.82 |
| 25. | Asiatic Bazaar | 0.713 | 0.520 | 2.618 | 1.911 | 26.18 | 15.29 | 172.51 | 229.37 |
| 26. | Watloo | 0.229 | 0.519 | 0.839 | 1.905 | 8.39 | 15.25 | 55.28 | 228.69 |
| 27. | Pretoria Central | 0.483 | 0.483 | 1.774 | 1.776 | 17.74 | 14.21 | 116.90 | 213.12 |
| 28. | Eloffsdal | 0.487 | 0.461 | 1.786 | 1.693 | 17.86 | 13.55 | 117.73 | 203.53 |
| 29. | Lynnwood | 0.508 | 0.460 | 1.864 | 1.690 | 18.64 | 13.53 | 122.86 | 202.90 |
| 30.. | Pretoria Gardens | 0.511 | 0.462 | 1.875 | 1.696 | 18.75 | 13.57 | 123.57 | 203.21 |
| 31. | Valhalla | 0.348 | 0.455 | 1.278 | 1.669 | 12.78 | 13.36 | 84.23 | 200.39 |
| 32. | Pretoria Industrial | 0.297 | 0.442 | 1.09 | 1.623 | 10.9 | 12.99 | 71.84 | 194.81 |
| 33. | Lisdogan Park | 0.415 | 0.434 | 1.523 | 1.595 | 15.23 | 12.76 | 100.38 | 191.45 |
| 34. | Waterkloof Ridge | 0.243 | 0.423 | 0.893 | 1.552 | 8.93 | 12.42 | 58.87 | 186.32 |
| 35. | Menlo Park | 0.458 | 0.416 | 1.683 | 1.530 | 16.83 | 12.24 | 110.89 | 183.63 |
| 36. | Brooklyn | 0.472 | 0.413 | 1.731 | 1.517 | 17.31 | 12.14 | 114.04 | 182.16 |
| 37. | La Montagne | 0.170 | 0.407 | 0.625 | 1.495 | 6.25 | 11.97 | 41.19 | 79.514 |
| 38. | Sunnyside | 0.430 | 0.394 | 1.576 | 1.447 | 15.57 | 11.58 | 103.89 | 173.72 |
| 39. | Ashlea Gardens | 0.263 | 0.393 | 0.965 | 1.445 | 9.65 | 11.56 | 63.56 | 173.43 |
| 40. | Clydesdale | 0.317 | 0.389 | 1.165 | 1.430 | 11.65 | 11.45 | 76.76 | 171.72 |
| 41. | Montana | 0.045 | 0.379 | 0.166 | 1.393 | 1.66 | 11.15 | 10.91 | 167.19 |
| 42. | Waterkloof Park | 0.127 | 0.363 | 0.468 | 1.335 | 4.68 | 10.68 | 30.83 | 160.26 |
| 43. | Hillcrest | 0.218 | 0.360 | 0.802 | 1.324 | 8.02 | 10.59 | 52.83 | 158.90 |
| 44. | Lynnwood Glen | 0.248 | 0.353 | 0.911 | 1.297 | 9.11 | 10.38 | 60.02 | 155.65 |
| 45. | Kilner Park | 0.121 | 0.351 | 0.444 | 1.288 | 4.44 | 10.31 | 29.23 | 154.58 |
| 46. | Lukasrand | 0.248 | 0.347 | 0.909 | 1.277 | 9.09 | 10.22 | 59.93 | 153.25 |
| 47. | Mamelodi | 0.094 | 0.335 | 0.345 | 1.231 | 3.45 | 9.85 | 22.71 | 147.72 |
| 48. | Alphen Park | 0.65 | 0.326 | 0.605 | 1.198 | 6.05 | 9.59 | 39.86 | 143.84 |
| 49. | Lynnwood Ridge | 0.063 | 0.319 | 0.233 | 1.173 | 2.33 | 9.39 | 15.35 | 140.78 |
| 50. | Maroelana | 0.127 | 0.308 | 0.466 | 1.131 | 4.66 | 9.05 | 30.71 | 135.77 |

| | Suburb | Mean t C per tree | | Mean t $CO_2$ per tree | | US$ | | ZAR | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 51. | Nieuw Muckleneuk | 0.407 | 0.303 | 1.495 | 1.115 | 14.95 | 8.92 | 98.55 | 133.80 |
| 52. | Philip Nel Park | 0.039 | 0.287 | 0.143 | 1.054 | 1.43 | 8.44 | 9.42 | 126.56 |
| 53. | Faerie Glen | 0.40 | 0.279 | 0.146 | 1.02 | 1.46 | 8.22 | 9.64 | 123.26 |
| 54. | Pretoria West | 0.424 | 0.276 | 1.557 | 1.013 | 15.57 | 8.11 | 102.61 | 121.63 |
| 55. | Salvokop | 0.462 | 0.267 | 1.694 | 0.981 | 16.94 | 7.85 | 111.64 | 117.73 |
| 56. | Hazelwood | 0.067 | 0.266 | 0.248 | 0.979 | 2.48 | 7.83 | 16.32 | 117.50 |
| 57. | Waterkloof Glen | 0.115 | 0.262 | 0.422 | 0.962 | 4.22 | 7.70 | 27.81 | 115.46 |
| 58. | Constantia Park | 0.131 | 0.258 | 0.48 | 0.949 | 4.8 | 7.59 | 31.61 | 113.90 |
| 59. | Erasmuskloof | 0.023 | 0.230 | 0.085 | 0.845 | 0.85 | 6.76 | 5.61 | 101.40 |
| 60. | Queenswood | 0.253 | 0.228 | 0.927 | 0.838 | 9.27 | 6.70 | 61.10 | 100.57 |
| 61. | Wingate Park | 0.004 | 0.214 | 0.014 | 0.787 | 0.14 | 6.30 | 0.90 | 94.47 |
| 62 | Garsfontein | 0.122 | 0.209 | 0.447 | 0.767 | 4.47 | 6.14 | 29.45 | 92.10 |
| 63. | Eastwood | 0.259 | 0.208 | 0.95 | 0.765 | 9.5 | 6.13 | 62.62 | 91.90 |
| 64. | Jan Niemand Park | 0.088 | 0.207 | 0.323 | 0.760 | 3.23 | 6.09 | 21.31 | 91.32 |
| 65. | Newlands | 0.006 | 0.206 | 0.021 | 0.759 | 0.21 | 6.07 | 1.40 | 91.12 |
| 66. | Moreleta Park | 0.065 | 0.202 | 0.237 | 0.741 | 2.37 | 5.93 | 15.60 | 88.99 |
| 67. | Mayville | 0.028 | 0.196 | 0.101 | 0.720 | 1.01 | 5.77 | 6.60 | 86.51 |
| 68. | Erasmusrand | 0.109 | 0.196 | 0.399 | 0.719 | 3.99 | 5.75 | 26.31 | 86.32 |
| 69. | Elardus Park | 0.013 | 0.195 | 0.046 | 0.716 | 0.46 | 5.73 | 3.05 | 85.94 |
| 70. | Attridgeville | 0.114 | 0.168 | 0.418 | 0.619 | 4.18 | 4.96 | 27.56 | 74.39 |
| 71 | Saulsvile | 0.014 | 0.167 | 0.051 | 0.614 | 0.51 | 4.91 | 3.37 | 73.70 |
| 72. | Meyers Park | 0.208 | 0.079 | 0.763 | 0.292 | 7.63 | 2.34 | 50.28 | 35.10 |


Figure 4.5: Map showing the Mean Carbon Dioxide Equivalent (tonne) per tree in 2019.

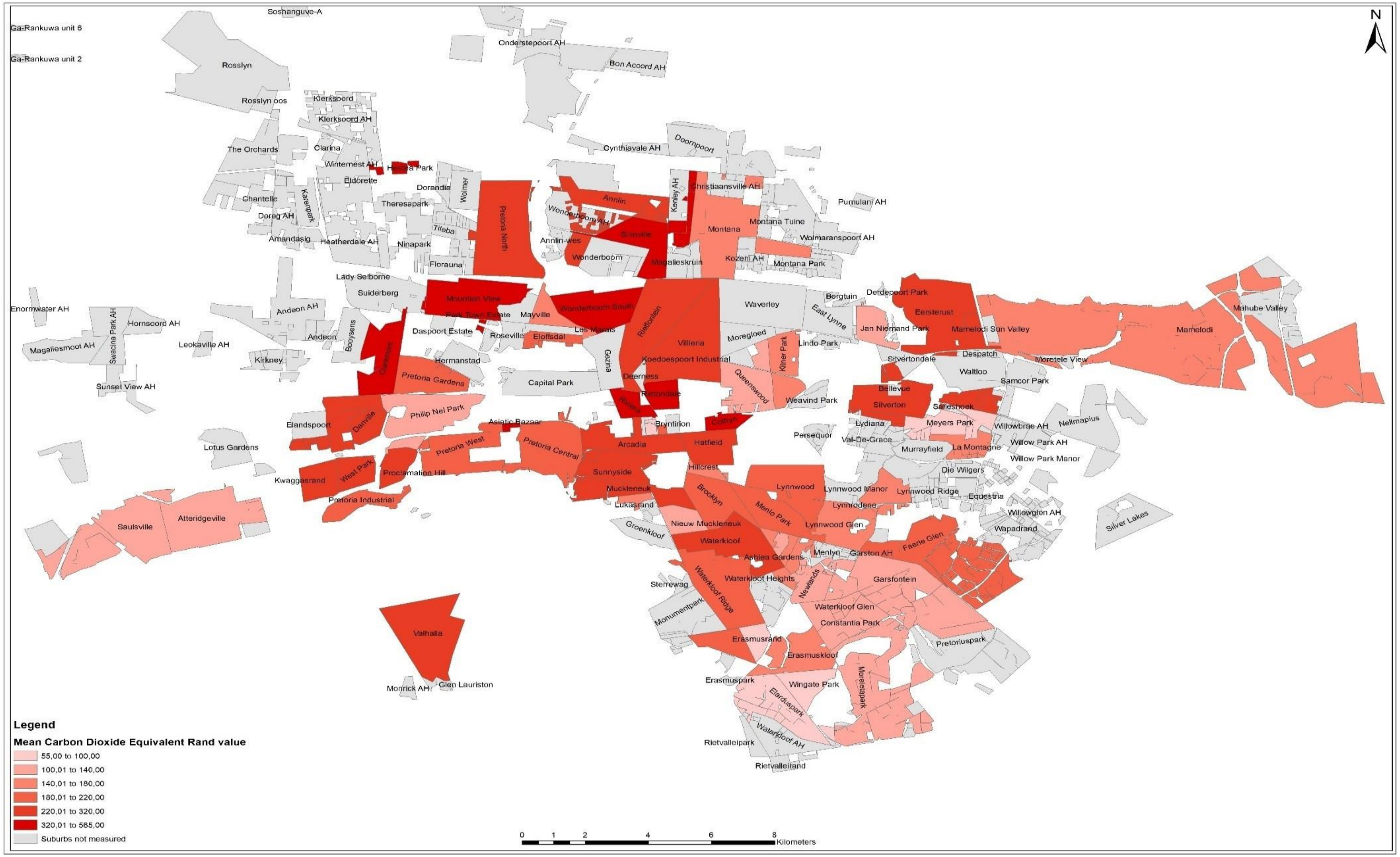


Figure 4.6: Map showing the Mean Carbon Dioxide Equivalent (tonnes) per tree Carbon Tax Rand value per tree in 2019.

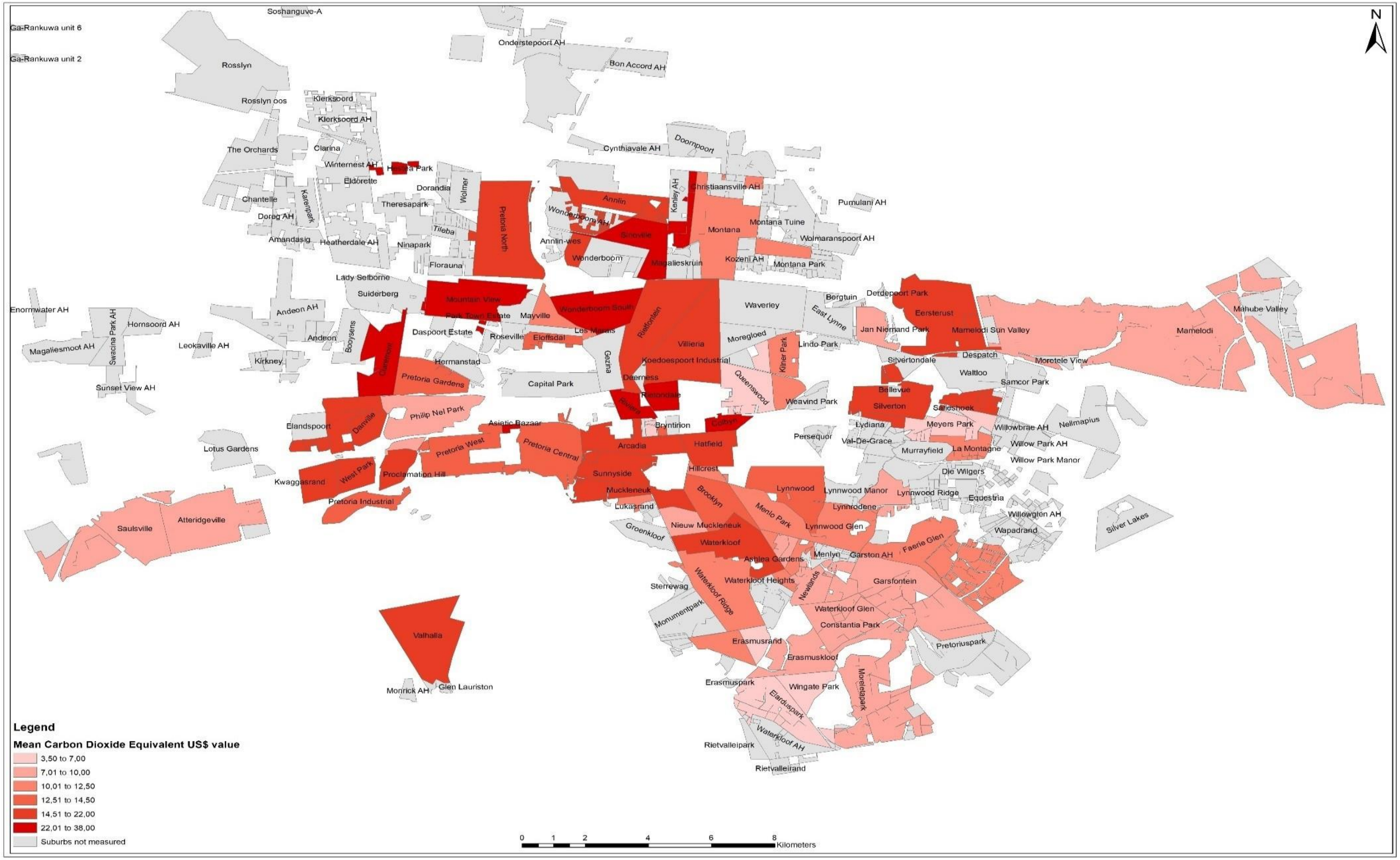


Figure 4.7: Map showing the Mean Carbon Dioxide Equivalent (tonnes) per tree US Dollar value for 2019.

### 4.2.4. Difference in the Mean Carbon values per tree and the associated monetary values between 2004 and 2019.

Table 4.11 shows the difference in Mean Carbon per tree, Mean $CO_2$ eq per tree and the associated US Dollar and Rand values of the Mean Carbon Dioxide Equivalent between 2004 and 2019. This study used the South African National Treasury's Carbon Tax Bill which states that 1 tonne of Carbon is equal to R120. This study used the exchange rate, relevant to the time of study, of US$1 being equal to R15.00 (businesstech.co.za, 2018). Therefore, to calculate the US$ value the Carbon Tax Rand value was divided by the exchange rate value above of US$1 Is equal to R15.

Figure 4.8 compares the Mean combined above ground and below ground Carbon per tree in 2004 and 2019. The highest differences occurred in Rietondale, Riviera, Hestea Park and Sinoville with estimated Mean Carbon increases of 0.759 t C, 0.757 t C, 0.720 t C and 0.479 t C, respectively. Suburbs that saw a decrease in the Mean Carbon sequestrated since the baseline study were Meyers Park, Pretoria West, Asiatic Bazaar and Salvokop. These suburbs saw an estimated decrease of 0.128 t C, 0.147 t C, 0.192 t C and 0.194 t C respectively since 2004.

Figure 4.9 compares the Mean combined above ground and below ground Carbon Dioxide Equivalent values per tree in 2004 and 2019. The highest differences occurred in Rietondale, Riviera, Hestea Park and Sinoville with estimated Mean Carbon Dioxide Equivalent increases of 2.787 t $CO_2$ eq, 2.779 t $CO_2$ eq, 2.643 t $CO_2$ eq and 1.758 t $CO_2$ eq, respectively. Suburbs that saw a decrease in the Mean Carbon per tree sequestrated since the baseline study were Meyers Park, Pretoria West, Asiatic Bazaar and Salvokop. These suburbs saw an estimated decrease of 0.470 t $CO_2$ eq, 0.543 t $CO_2$ eq, 0.706 t $CO_2$ eq and 0.712 t $CO_2$ eq respectively since 2004 (See figure 4.10)

Figure 4.11 compares the Mean Carbon Dioxide Equivalent per tree US Dollar amounts in 2004 and 2019. The highest differences occurred in Hestea Park, Rietondale, Riviera and Eesterust with an estimated US Dollar increase of US$ 21.08, US$ 18.87, US$ 18.45 and US$ 11.25, respectively. Suburbs that saw the highest US Dollar decrease were Montana, Pretoria West, Salvokop and Asiatic Bazaar. These suburbs saw an estimated US Dollar decrease of US$ 6.27, US$ 7.46, US$ 9.09 and US$ 10.88 respectively since 2004 (See figure 4.12)

Figure 4.13 compares the Mean Carbon Dioxide Equivalent per tree Carbon Tax Rand amounts in 2004 and 2019. The highest differences occurred in Riviera, Rietondale, Colbyn and Sinoville with an estimated Rand increase of R435.93, R427.15, R2326.78 and R320.80, respectively. Suburbs that saw the lowest Rand increases were Eastwood Pretoria West and Salvokop. These suburbs saw an estimated increase of R29.29, R19.02 and R6.08 respectively since 2004. Meyers Park had the highest decrease with an estimated Rand value decrease of R15.18 since 2004 (See figure 4.14).

Table 4.11 shows the difference in Mean Carbon (tonne), Mean Carbon Dioxide Equivalent (tonne) and the associated Mean Carbon Dioxide Equivalent US Dollar and Rand values between 2004 and 2019.

| | **Suburb Name** | **Difference in Mean Carbon** | **Difference in Mean $CO_2$ eq** | **Difference in US$ amount of the Mean $CO_2$ eq** | **Difference in ZAR amount of the Mean $CO_2$ eq** |
|---|---|---|---|---|---|
| 1 | Alphen Park | 0.16 | 0.59 | 3.54 | 103.98 |
| 2 | Annlin | 0.29 | 1.05 | 5.78 | 197.57 |
| 3 | Arcadia | 0.22 | 0.79 | 3.63 | 167.86 |
| 4 | Asiatic Bazaar | -0.19 | -0.70 | -10.89 | 56.86 |
| 5 | Ashlea Gardens | 0.05 | 0.17 | -0.56 | 72.72 |
| 6 | Atteridgeville | 0.05 | 0.20 | 0.78 | 46.83 |
| 7 | Brooklyn | -0.06 | -0.21 | -5.17 | 68.12 |
| 8 | Claremont | 0.06 | 0.21 | -3.17 | 159.42 |
| 9 | Clydesdale | 0.07 | 0.26 | -0.20 | 94.96 |
| 10 | Colbyn | 0.46 | 1.67 | 8.79 | 326.78 |
| 11 | Constantia Park | 0.13 | 0.46 | 2.79 | 82.28 |
| 12 | Danville | 0.33 | 1.21 | 7.76 | 199.61 |
| 13 | Eastwood | -0.05 | -0.18 | -3.37 | 29.29 |
| 14 | Eersterust | 0.44 | 1.61 | 11.26 | 239.07 |
| 15 | Elardus Park | 0.18 | 0.67 | 5.27 | 82.90 |
| 16 | Eloffsdal | -0.03 | -0.09 | -4.31 | 85.49 |
| 17 | Erasmusrand | 0.09 | 0.32 | 1.76 | 60.01 |
| 18 | Erasmuskloof | 0.21 | 0.76 | 5.91 | 95.79 |
| 19 | Faerie Glen | 0.24 | 0.88 | 6.76 | 113.62 |
| 20 | Garsfontein | 0.09 | 0.32 | 1.67 | 62.65 |
| 21 | Hatfield | 0.17 | 0.62 | 2.18 | 151.50 |
| 22 | Hazelwood | 0.20 | 0.73 | 5.35 | 101.18 |
| 23 | Hestea Park | 0.72 | 2.64 | 21.08 | 319.03 |
| 24 | Hillcrest | 0.14 | 0.52 | 2.57 | 106.07 |
| 25 | Jan Niemand Park | 0.12 | 0.43 | 2.86 | 70.01 |
| 26 | Kilner Park | 0.23 | 0.84 | 5.87 | 125.36 |
| 27 | Kwaggasrand | 0.32 | 1.18 | 6.91 | 212.19 |
| 28 | La Montagne | 0.15 | 0.55 | 3.17 | 100.10 |

| | Suburb Name | Difference in Mean Carbon | Difference in Mean $CO_2$ eq | Difference in US$ amount of the Mean $CO_2$ eq | Difference in ZAR amount of the Mean $CO_2$ eq |
|---|---|---|---|---|---|
| 29 | Laudium | 0.02 | 0.08 | -4.35 | 144.73 |
| 30 | Lisdogan Park | 0.02 | 0.07 | -2.47 | 91.07 |
| 31 | Lukasrand | 0.10 | 0.36 | 1.13 | 93.32 |
| 32 | Lynnwood | -0.05 | -0.17 | -5.11 | 80.04 |
| 33 | Lynnwood Glen | 0.11 | 0.38 | 1.27 | 95.64 |
| 34 | Lynnwood Ridge | 0.26 | 0.94 | 7.06 | 125.44 |
| 35 | Mamelodi | 0.24 | 0.88 | 6.40 | 125.01 |
| 36 | Maroelana | 0.18 | 0.66 | 4.39 | 105.07 |
| 37 | Mayville | 0.17 | 0.61 | 4.76 | 79.85 |
| 38 | Menlo Park | -0.04 | -0.15 | -4.59 | 72.75 |
| 39 | Meyers Park | -0.13 | -0.47 | -5.29 | -15.18 |
| 40 | Montana | 0.33 | 1.22 | 9.49 | 156.28 |
| 41 | Moreleta Park | 0.14 | 0.50 | 3.56 | 73.39 |
| 42 | Mountain View | -0.06 | -0.22 | -6.27 | 94.79 |
| 43 | Muckleneuk | 0.20 | 0.72 | 1.97 | 190.06 |
| 44 | Newlands | 0.20 | 0.73 | 5.86 | 89.72 |
| 45 | Nieuw Muckleneuk | -0.10 | -0.37 | -6.03 | 35.26 |
| 46 | Philip Nel Park | 0.25 | 0.91 | 7.01 | 117.14 |
| 47 | Pretoria Central | 0.001 | 0.002 | -3.53 | 96.23 |
| 48 | Pretoria Gardens | -0.05 | -0.17 | -5.18 | 79.96 |
| 49 | Pretoria Industrial | 0.15 | 0.53 | 2.09 | 122.97 |
| 50 | Pretoria North | 0.13 | 0.46 | 0.46 | 143.71 |
| 51 | Pretoria West | -0.15 | -0.54 | -7.46 | 19.02 |
| 52 | Proclamation Hill | 0,17 | 0.63 | 2.19 | 154.12 |
| 53 | Queenswood | -0.02 | -0.08 | -2.57 | 39.47 |
| 54 | Rietfontein | 0.11 | 0.39 | -0.18 | 139.31 |
| 55 | Rietondale | 0.76 | 2.78 | 18.87 | 427.15 |
| 56 | Riviera | 0.76 | 2.77 | 18.46 | 435.94 |
| 57 | Saulsville | 0.15 | 0.56 | 4.40 | 70.33 |
| 58 | Salvokop | -0.19 | -0.71 | -9.09 | 6.09 |
| 59 | Silverton | 0.35 | 1.27 | 7.74 | 218.61 |
| 60 | Sinoville | 0.48 | 1.75 | 10.01 | 320.81 |

| | Suburb Name | Difference in Mean Carbon | Difference in Mean $CO_2$ eq | Difference in US$ amount of the Mean $CO_2$ eq | Difference in ZAR amount of the Mean $CO_2$ eq |
|---|---|---|---|---|---|
| 61 | Sunnyside | -0.04 | -0.12 | -4.18 | 69.83 |
| 62 | Trevena | 0.14 | 0.52 | 1.19 | 145.99 |
| 63 | Valhalla | 0.11 | 0.39 | 0.58 | 116.16 |
| 64 | Villiera | 0.24 | 0.89 | 3.78 | 198.11 |
| 65 | Waterkloof | 0.003 | -0.009 | -4.24 | 111.56 |
| 66 | Waterkloof Glen | 0.15 | 0.54 | 3.48 | 87.66 |
| 67 | Waterkloof Park | 0.24 | 0.86 | 6.00 | 129.44 |
| 68 | Waterkloof Ridge | 0.18 | 0.65 | 3.49 | 127.45 |
| 69 | Wespark | 0.36 | 1.32 | 8.55 | 213.86 |
| 70 | Watloo | 0.29 | 1.06 | 6.86 | 173.42 |
| 71 | Wingate Park | 0.17 | 0.60 | 4.83 | 73.66 |
| 72 | Wonderboom South | 0.36 | 1.31 | 6.29 | 273.74 |

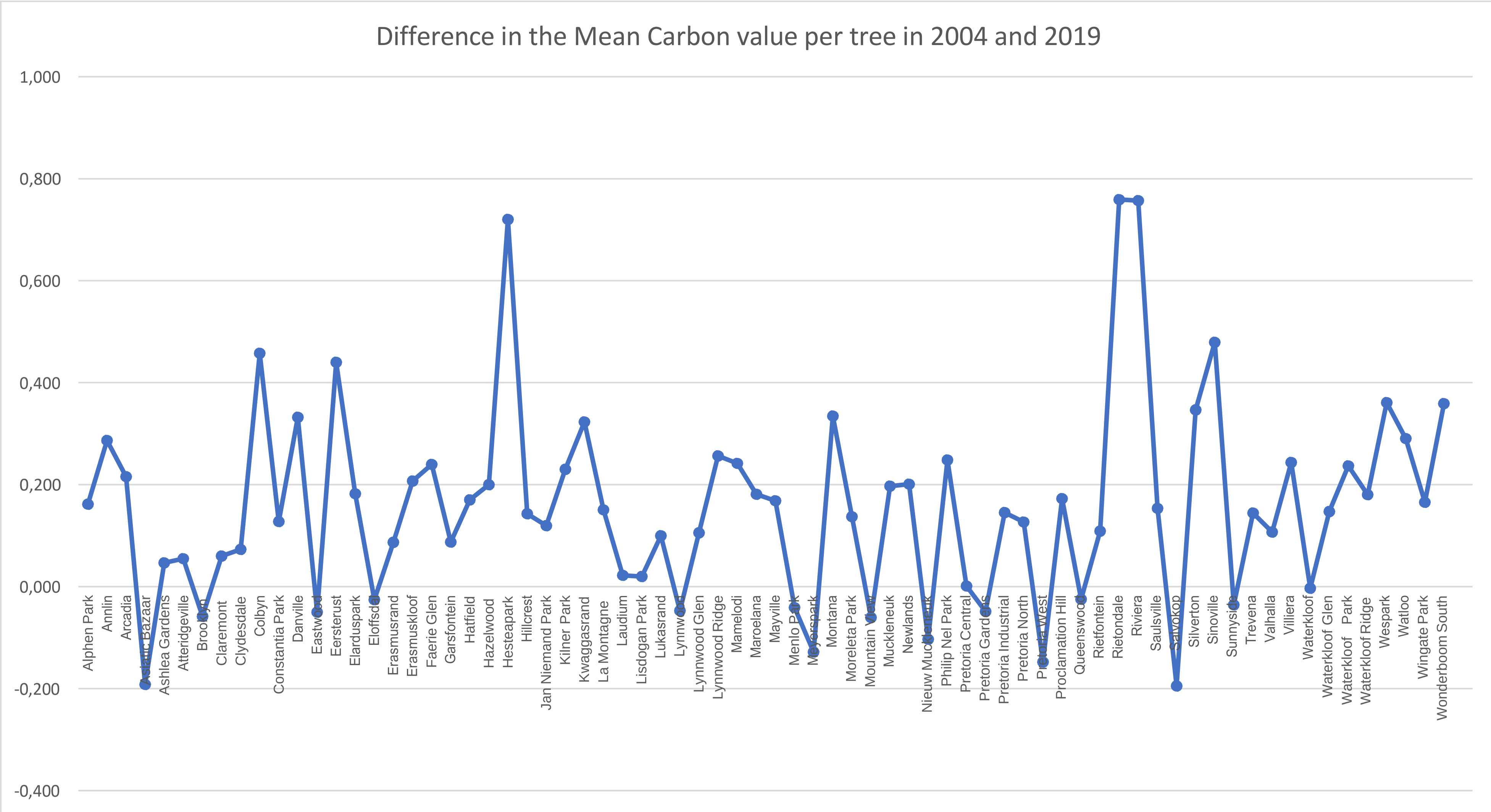


Figure 4.8: Mean Carbon difference per suburb between 2004 and 2019.

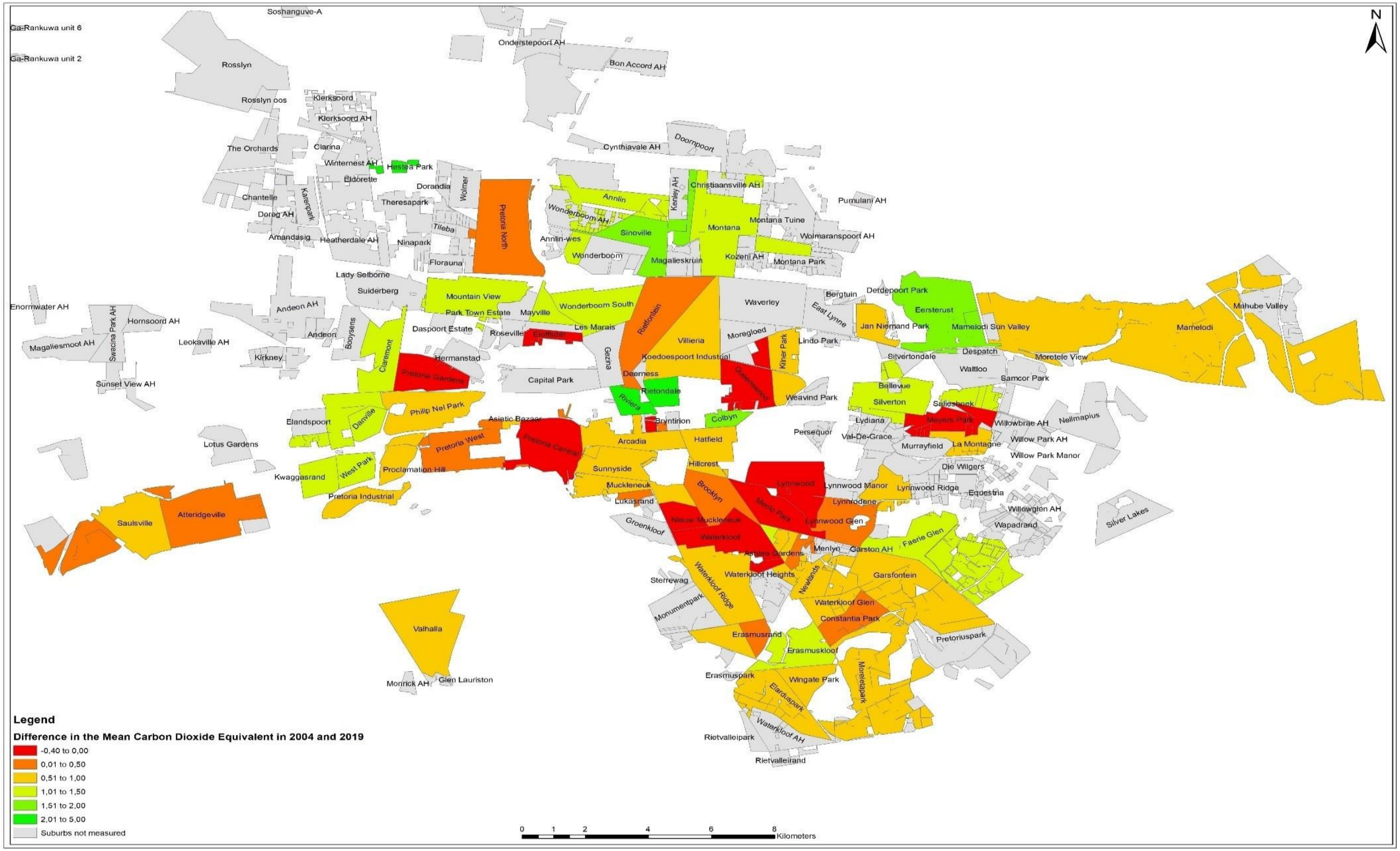


Figure 4.9: Map comparing the Mean Carbon Dioxide Equivalent per tree in 2004 and 2019.

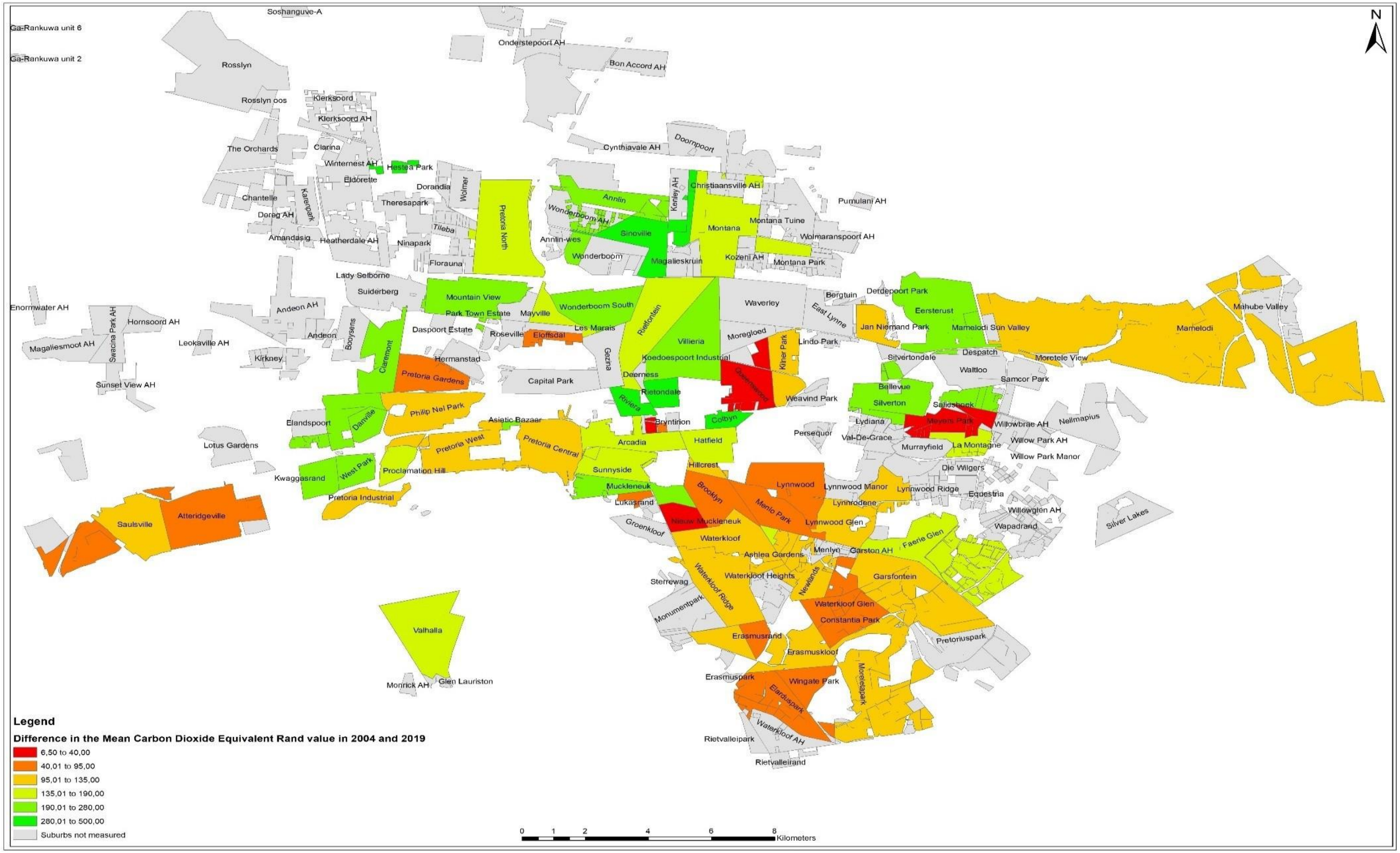


Figure 4.10: Map comparing the Mean Carbon Dioxide Equivalent Carbon Tax Rand value per suburb in 2004 and 2019.

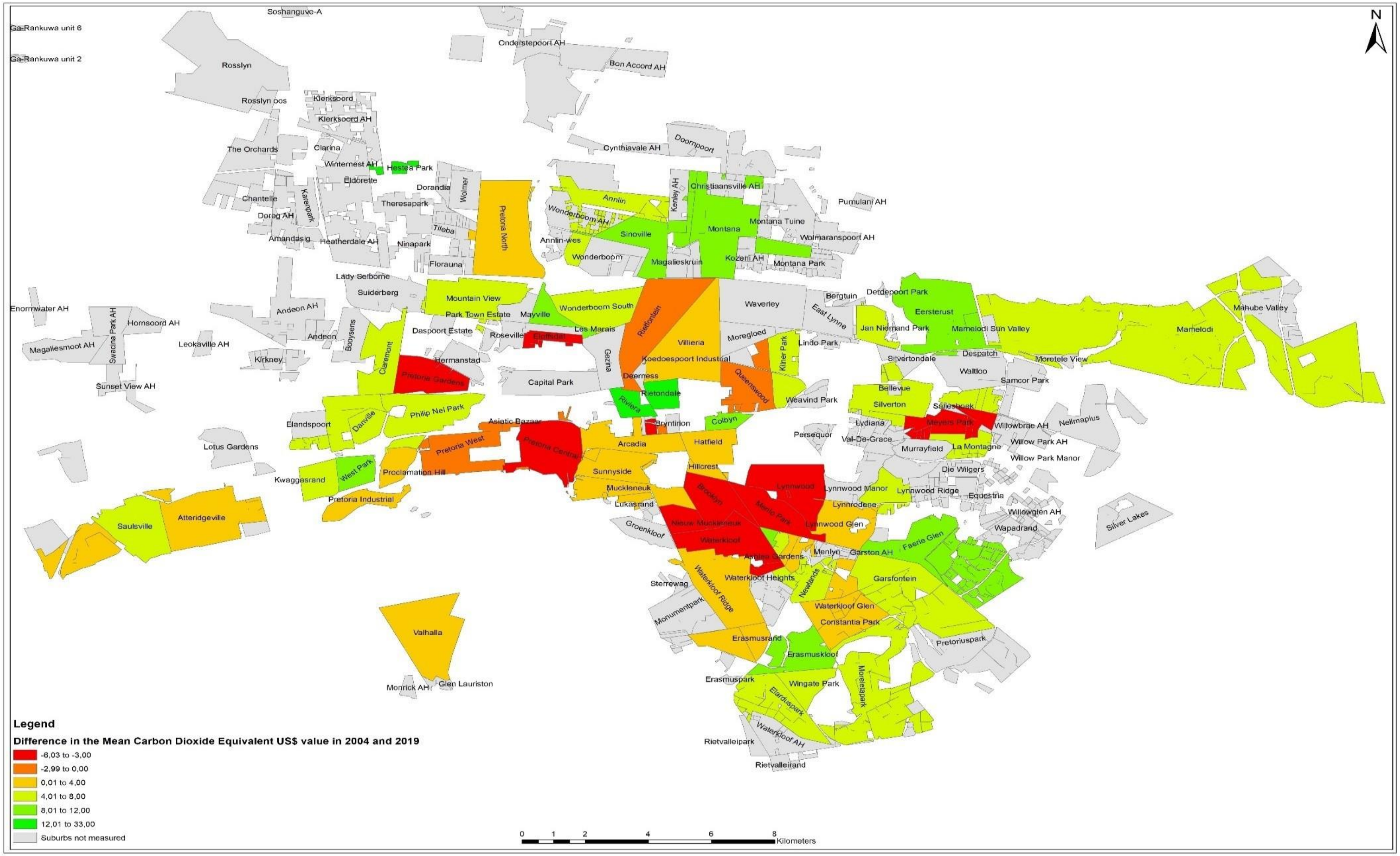


Figure 4.11: Map comparing the Mean Carbon Dioxide Equivalent US Dollar value per suburb in 2004 and 2019.

### 4.2.5. Total Carbon, Total Carbon Dioxide Equivalents and the associated monetary values

Table 4.12 shows the suburb name, the Total Carbon (tonne), the Total Carbon Dioxide Equivalent per suburb, the associated Rand and US$ Dollar values based on the exchange rate of 1$ = R15. 00 and Rand value based on National Treasury's 1 tonne of Carbon =R120 for the Total Carbon Dioxide Equivalent as well as the corresponding percentages in 2004 and 2019 in alphabetic order.

Table 4.13 shows the suburb name, the Total Carbon (tonne), the Total Carbon Dioxide Equivalent (tonne), the associated Rand and Dollar values based on the exchange rate of 1$ = R15. 00 and Rand value based on National Treasury's 1 tonne of Carbon =R120 for the Total Carbon Dioxide Equivalent as well as the corresponding percentages in relation to the total Rand value for all the suburbs in descending order for the baseline study (2004). The suburbs with the highest Total Carbon amounts were Pretoria Central, Brooklyn, Waterkloof and Sunnyside. The estimated above ground and below ground Total Carbon was 1379.03 t C, 1195.35, 801.35 and 788.65, respectively. The estimated above ground and below ground $CO_2$ equivalent amounts were 5061.06 t $CO_2$ eq, 4386.93 t $CO_2$ eq, 2940.98 t $CO_2$ eq and 724.21 t $CO_2$ eq with an estimated value of R333 524.29 (11.29%), R289 099.26 (9.79%), R193 811.08 (6.56%) and R190 737.60 (6.46%) respectively. The suburbs with the lowest Total Carbon amounts were Mayville, Hestea Park, Newlands and Wingate Park. The estimated above ground and below ground Total Carbon amounts were 1.15 t C, 0.91 t C, 0.34 t C and 0.34 t C, respectively. The estimated above ground and below ground $CO_2$ equivalent amounts were 4.24 t $CO_2$ eq, 3.35 t $CO_2$ eq, 1.27 t $CO_2$ eq and 1.26 t $CO_2$ eq with an estimated value of R279. 51 (0.009%), R220.87 (0.007%), R83.77 (0,003%) and R83.10 (0.003%) respectively.

Table 4.14 shows the suburb name, the Total Carbon (tonne), the Total Carbon Dioxide Equivalent, the associated Rand and Dollar values based on the exchange rate of 1$ = R15. 00 and Rand value based on National Treasury's 1 tonne of Carbon =R120 for the Total Carbon Dioxide Equivalent as well as the corresponding percentages in relation to the total Rand value for all the suburbs in descending order for this study (2019). The suburbs with the highest Total Carbon amounts were Pretoria Central, Arcadia, Brooklyn and Villiera. The estimated above ground and below ground Total Carbon per suburb was 180.68 t C, 1124.49 t C, 1048.53 t C and 846.54 t C, respectively. The estimated above ground and below ground $CO_2$ equivalent amounts were 5067.12 t $CO_2$ eq, 4126.80 t $CO_2$ eq, 3848.11 t $CO_2$ eq and 3106.80 t $CO_2$ eq with an estimated value of R608 055.41 (8.59%), R495 216.19 (7.00%), R461 774.31 (6.52%) and R372 816.84 (4.87%) respectively. The suburbs with the lowest Total Carbon amounts were Wingate Park, Jan Niemand Park, Newlands and Mayville. The estimated above ground and below ground Total Carbon amounts were 15.57 t C, 12.64 t C, 12.44 t C and 8.25 t C, respectively. The estimated above ground and below ground $CO_2$ equivalent amounts were 57.16 t $CO_2$ eq, 46.42 t $CO_2$ eq, 45.56 t $CO_2$ eq and 30.27 t $CO_2$ eq with an estimated value of R6 859.55 (0.09%), R5 570.48 (0.07%), R5 467.44 (0,07%) and R3 633.52 (0.05%) respectively.

Figure 4.15 shows the 45.56 t Total Carbon per suburb in 2019.The darker colours are representative of the suburbs with the highest total carbon per suburb.

Figure 4.16 shows the Total Carbon Dioxide Equivalent per suburb in 2019. The darker colours are representative of the suburbs with the highest total carbon dioxide equivalent values per suburb in 2019.

Figure 4.17 shows the Total Carbon Dioxide Equivalent Rand values per suburb in 2019. The darker colours are representative of the suburbs with the highest Rand values.

Figure 4.18 shows the Total Carbon Dioxide Equivalent US Dollar values per suburb in 2019. The darker colours are representative of the suburbs with the highest US Dollar values.

Table 4.12 shows the suburb name, the Total Carbon (tonne), the Total Carbon Dioxide Equivalent per suburb, the associated Carbon Tax Rand and Dollar values based on the exchange rate of 1$ = R15. 00 and Rand value based on National Treasury's 1 tonne of Carbon =R120 for the Total Carbon Dioxide Equivalent as well as the corresponding percentages in 2004 and 2019 in *alphabetic* order.

| | **Suburb** | **Total t C per suburb** | | **Total t $CO_2$eq per suburb** | | **US$** | | **ZAR** | | **% of Total** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2004** | **2019** | **2004** | **2019** | **2004** | **2019** | **2004** | **2019** | **2004** | **2019** |
| 1. | Alphen Park | 15.83 | 31.355 | 58.07 | 115.07 | 580.70 | 920.60 | 3826.79 | 13809.01 | 0.13 | 0.17 |
| 2. | Annlin | 176.62 | 317.706 | 648.22 | 1165.98 | 6482.22 | 9327.868 | 42717.84 | 139918.02 | 1.44 | 1.82 |
| 3. | Arcadia | 708.77 | 1124.469 | 175.29 | 4126.80 | 1753.92 | 33014.41 | 11558.34 | 495216.19 | 5.80 | 5.46 |
| 4. | Asiatic Bazaar | 47.79 | 34.892 | 175.39 | 128.06 | 1753.92 | 1024.54 | 11558.34 | 15 368.09 | 0.39 | 0.217 |
| 5. | Ashlea Gardens | 107.49 | 126.559 | 394.49 | 464.47 | 3944.92 | 3715.77 | 25997.00 | 55736.20 | 0.88 | 0.788 |
| 6. | Atteridgeville | 30.54 | 45.267 | 112.09 | 166.13 | 1120.98 | 1329.05 | 7387.29 | 19935.82 | 0.25 | 0.282 |
| 7. | Brooklyn | 1195.35 | 1048.533 | 4386.93 | 3848.11 | 43869.39 | 30784.96 | 289099.26 | 461774.34 | 9.79 | 6.529 |
| 8. | Claremont | 230.64 | 251.189 | 846.45 | 921.86 | 8464.57 | 7374.93 | 55781..49 | 110623.94 | 1.88 | 1.564 |
| 9. | Clydesdale | 21.26 | 26.123 | 78.04 | 95.87 | 780.44 | 767.00 | 5143.09 | 11504.95 | 0.17 | 0.163 |
| 10. | Colbyn | 194.43 | 335.318 | 713.58 | 1230.62 | 7135.80 | 9844.964 | 47024.92 | 147674.47 | 1.59 | 1.92 |
| 11. | Constantia Park | 51.38 | 101.641 | 188.58 | 373.02 | 1885.88 | 2984.194 | 12427.97 | 44762.90 | 0.42 | 0.58 |
| 12. | Danville | 18.05 | 40.28 | 66.24 | 147.82 | 662.47 | 1182.638 | 4365.68 | 17739.58 | 0.14 | 0.23 |
| 13. | Eastwood | 129.20 | 104.135 | 474.16 | 382.17 | 4741.68 | 3057.426 | 31247.70 | 45861.8 | 1.05 | 0.59 |
| 14. | Eersterust | 100.60 | 295.185 | 369.21 | 1083.33 | 3692.11 | 8666.643 | 24330.99 | 129999.65 | 0.85 | 1.69 |
| 15. | Elardus Park | 2.00 | 31.029 | 7.36 | 113.87 | 73.64 | 911.027 | 485.29 | 13665.41 | 0.01 | 0.17 |
| 16. | Eloffsdal | 77.39 | 73.368 | 284.04 | 296.26 | 2840.44 | 2154.097 | 18718.52 | 32311.46 | 0.63 | 0.42 |
| 17. | Erasmusrand | 24.69 | 44.49 | 90.61 | 163.29 | 906.18 | 1306.36 | 5971.72 | 19595 | 0.20 | 0.25 |
| 18. | Erasmuskloof | 1.62 | 16.117'f | 5.96 | 59.15 | 59.63 | 473.22 | 392.95 | 7098.23 | 0.01 | 0.100 |
| 19. | Faerie Glen | 8.88 | 62.415 | 32.62 | 229.06 | 326.23 | 1832.51 | 2149.86 | 27487.69 | 0.07 | 0.389 |
| 20. | Garsfontein | 54.67 | 93.901 | 200.63 | 344.61 | 2006.39 | 2756.95 | 13222.09 | 41354.18 | 0.44 | 0.585 |

| | Suburb | Total t C per suburb | | Total t $CO_2$eq per suburb | | US$ | | ZAR | | % of Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 21. | Hatfield | 375.98 | 542.573 | 1379.87 | 1991.24 | 13798.70 | 15929.96 | 90933.43 | 238949.47 | 3.08 | 3.12 |
| 22. | Hazelwood | 5.197 | 20.544 | 19.072 | 75.39 | 190.72 | 603.18 | 1256.82 | 9047.63 | 0.04 | 0.128 |
| 23. | Hestea Park | 0.913 | 75.113 | 3.35 | 275.66 | 33.52 | 2205.34 | 220.87 | 33080.17 | 0.007 | 0.468 |
| 24. | Hillcrest | 33.85 | 55.92 | 124.26 | 205.25 | 1242.61 | 1642.001 | 8188.82 | 24630.02 | 0.27 | 0.32 |
| 25. | Jan Niemand Park | 5.375 | 12.648 | 19.72 | 46.42 | 197.28 | 371.37 | 1300.05 | 5570.48 | 0.04 | 0.079 |
| 26. | Kilner Park | 28.40 | 82.48 | 104.25 | 302.72 | 1042.51 | 2421.84 | 6870.12 | 36327.60 | 0.23 | 0.47 |
| 27. | Kwaggasrand | 109.05 | 209.251 | 400.21 | 767.95 | 4002.17 | 6143.623 | 26374.29 | 92154.34 | 0.89 | 1.20 |
| 28. | La Montagne | 10.04 | 18.929 | 36.87 | 69.46 | 368.74 | 555.76 | 2430.00 | 8336.33 | 0.08 | 0.118. |
| 29. | Laudium | 191.18 | 197.340 | 701.64 | 724.23 | 7016.47 | 5793.92 | 46238.51 | 86908.77 | 1.56 | 1.229 |
| 30. | Lisdogan Park | 220.38 | 230.835 | 808.82 | 847.16 | 8088.20 | 6777.321 | 53301.21 | 101659.81 | 1.80 | 1.32 |
| 31. | Lukasrand | 80.04 | 112.397 | 293.75 | 412.49 | 2937.53 | 3300 | 19358.31 | 49499.99 | 0.65 | 0.64 |
| 32. | Lynnwood | 261.11 | 236.810 | 958.27 | 869.09 | 9582.73 | 6952.76 | 63150.16 | 104291.47 | 2.13 | 1.474 |
| 33. | Lynnwood Glen | 25.31 | 36.05 | 92.89 | 132.30 | 928.93 | 1058.477 | 6121.64 | 15877.15 | 0.20 | 0.20 |
| 34. | Lynnwood Ridge | 6.85 | 34.52 | 25.16 | 126.70 | 251.61 | 1013.667 | 1658.10 | 15205.00 | 0.05 | 0.19 |
| 35. | Mamelodi | 28.54 | 101.96 | 104.77 | 374.22 | 1047.75 | 2993.794 | 6904.64 | 44906.91 | 0.23 | 0.58 |
| 36. | Maroelana | 7.61 | 18.49 | 27.96 | 67.88 | 279.63 | 543.117 | 1842.73 | 8146.77 | 0.06 | 0.10 |
| 37. | Mayville | 1.15 | 8.250 | 4.24 | 30.27 | 42.41 | 242.23 | 279.51 | 3633.52 | 0.009 | 0.051 |
| 38. | Menlo Park | 173.31 | 157.61 | 636.04 | 578.46 | 6360.49 | 4627.709 | 41915.60 | 69415.64 | 1.420 | 0.90 |
| 39. | Meyers Park | 48.85 | 18.72 | 179.29 | 68.73 | 1792.96 | 549.87 | 11815.62 | 8248.09 | 0.400 | 0.117 |
| 40. | Montana | 4.19 | 35.306 | 15.39 | 129.57 | 153.95 | 1036.589 | 1014.56 | 15548.83 | 0.03 | 0.20 |
| 41. | Moreleta Park | 22.45 | 70.321 | 82.39 | 258.07 | 823.99 | 2064.63 | 5430.12 | 30969.42 | 0.18 | 0.438 |
| 42. | Mountain View | 93.64 | 84.357 | 343.67 | 309.59 | 3436.76 | 2476.74 | 22648.28 | 37151.16 | 0.7 | 0.525 |
| 43. | Muckleneuk | 290.64 | 400.853 | 1066.67 | 1471.13 | 10666.67 | 11769.07 | 70293.90 | 176536.00 | 2.38 | 2.30 |
| 44. | Newlands | 0.346 | 12.414 | 1.27 | 45.56 | 12.71 | 364.50 | 83.77 | 5467.44 | 0.003 | 0.077 |
| 45. | Nieuw Muckleneuk | 115.72 | 86.287 | 424.7 | 316.67 | 4247.03 | 2533.406 | 27987.93 | 38001.09 | 0.948 | 0.49 |
| 46. | Philip Nel Park | 2.18 | 16.093 | 8.00 | 59.06 | 80.07 | 472.497 | 527.65 | 7087.46 | 0.01 | 0.093 |

| | Suburb | Total t C per suburb | | Total t $CO_2$eq per suburb | | US$ | | ZAR | | % of Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 47. | Pretoria Central | 1379.03 | 1380.688 | 5061.06 | 5067.12 | 50610.67 | 40537.03 | 333524.29 | 608055.41 | 11.29 | 7.94 |
| 48. | Pretoria Gardens | 67.44 | 61.004 | 247.52 | 223.88 | 2475.24 | 1791.082 | 16311.82 | 26866.23 | 0.55 | 0.35 |
| 49. | Pretoria Industrial | 117.62 | 175.172 | 431.67 | 642.88 | 4316.76 | 5143.06 | 28447.47 | 77145.90 | 0.96 | 1.00 |
| 50. | Pretoria North | 372.49 | 478.673 | 1367.06 | 1756.73 | 13670.64 | 14053.85 | 90089.54 | 210807.76 | 3.05 | 2.75 |
| 51. | Pretoria West | 297.84 | 193.884 | 1093.08 | 711.55 | 131169.6 | 5692.44 | 8744.64 | 85386.59 | 2.35 | 1.207 |
| 52. | Proclamation Hill | 352.157 | 506.955 | 1292.41 | 1860.52 | 155089.2 | 14884.21 | 10339.28 | 223263.12 | 2.78 | 2.91 |
| 53. | Queenswood | 54.31 | 49.099 | 199.33 | 180.19 | 23919.6 | 1441.55 | 1594.64 | 21623.26 | 0.42 | 0.28 |
| 54. | Rietfontein | 473.02 | 584.970 | 1735.98 | 2146.84 | 208317.6 | 17174.74 | 13887.84 | 257621.12 | 3.73 | 3.36 |
| 55. | Rietondale | 211.94 | 556.730 | 777.82 | 2043.20 | 93338.4 | 16345.62 | 6222.56 | 245.184.30 | 1.67 | 3.2 |
| 56. | Riviera | 239.76 | 591.952 | 879.92 | 2172.46 | 105590.4 | 17379.71 | 7039.36 | 260695.72 | 1.89 | 3.40 |
| 57. | Saulsville | 2.900 | 34.807 | 10.64 | 127.74 | 1277.4 | 1021.94 | 85.16 | 15329.17 | 0.02 | 0.217 |
| 58. | Salvokop | 40.15 | 23.257 | 147.38 | 85.35 | 17685.6 | 682.83 | 1179.04 | 10242.42 | 0.31 | 0.145 |
| 59. | Silverton | 55.08 | 112.648 | 202.14 | 413.41 | 24256.8 | 3307.353 | 1617.12 | 49610.30 | 0.43 | 0.64 |
| 60. | Sinoville | 45.35 | 84.641 | 166.46 | 310.63 | 19975.2 | 2485.07 | 1331.68 | 37276.05 | 0.35 | 0.48 |
| 61. | Sunnyside | 788.65 | 724.217 | 2894.34 | 2657.87 | 347320.8 | 21263.03 | 23154.72 | 318945.40 | 6.22 | 4.509 |
| 62. | Trevena | 53.11 | 71.59 | 194.91 | 262.76 | 23389.2 | 2102.092 | 1559.28 | 31531 | 0.41 | 0.41 |
| 63. | Valhalla | 155.68 | 203.395 | 571.35 | 746.45 | 68562 | 5971.68 | 4570.8 | 89575.16 | 1.22 | 1.266 |
| 64. | Villiera | 552.80 | 846.541 | 2028.79 | 3106.80 | 243454.8 | 24854.46 | 16230.32 | 372816.84 | 4.36 | 4.87 |
| 65. | Waterkloof | 801.35 | 797.766 | 2940.98 | 2927.80 | 352917.6 | 23422.42 | 23527.84 | 351336.24 | 6.32 | 4.58 |
| 66. | Waterkloof Glen | 17.82 | 40.639 | 65.41 | 149.14 | 7849.2 | 1193.167 | 523.28 | 17897.51 | 0.14 | 0.23 |
| 67. | Waterkloof Park | 24.09 | 68.779 | 88.43 | 252.42 | 10611.6 | 2019.368 | 707.44 | 30290.52 | 0.19 | 0.39 |
| 68. | Waterkloof Ridge | 367.28 | 638.415 | 1347.94 | 2324.98 | 161752.8 | 18743.88 | 10783.52 | 281158.23 | 2.90 | 3.67 |
| 69. | Wespark | 172.48 | 396.773 | 633.01 | 1456.15 | 7596.2 | 11649.27 | 5064.08 | 174739.09 | 1.36 | 2.28 |
| 70. | Watloo | 56.68 | 128.785 | 2018.02 | 472.64 | 242162.4 | 3781.13 | 16144.16 | 56716.95 | 4.34 | 0.74 |
| 71. | Wingate Park | 0.34 | 15.575 | 1.26 | 57.16 | 151.32 | 457.30 | 10.08 | 6859.55 | 0.002 | 0.097 |
| 72. | Wonderboom South | 132.01 | 213.593 | 484.49 | 783.88 | 58138.8 | 6271.094 | 3875.92 | 94066.41 | 1.04 | 1.22 |

Table 4.13 shows the suburb name, the Total Carbon (tonne), the Total Carbon Dioxide Equivalent (tonne) per suburb, the associated Total Carbon Dioxide Equivalent Rand and US Dollar values. This data is reflected in *descending* order for 2004.

| | Suburb | Total t C per suburb | | Total t $CO_2$eq per suburb | | US$ | | ZAR | | % of Total ZAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 1. | Pretoria Central | 1379.03 | 1380.68 | 5061.06 | 5067.12 | 50610.67 | 40537.03 | 333524.29 | 608055.41 | 11.29 | 8.59 |
| 2. | Brooklyn | 1195.35 | 1048.53 | 4386.93 | 3848.11 | 43869.39 | 30784.96 | 289099.26 | 461774.34 | 9.79 | 6.52 |
| 3. | Waterkloof | 801.35 | 797.76 | 2940.98 | 2927.80 | 29409.88 | 23422.42 | 193811.08 | 351336.24 | 6.56 | 4.58 |
| 4. | Sunnyside | 788.65 | 724.21 | 2894.34 | 2656.87 | 28943.49 | 21253.03 | 190737.60 | 218945.40 | 6.46 | 4.50 |
| 5. | Arcadia | 708.77 | 1124.46 | 2601.20 | 4126.80 | 26012.08 | 33014.41 | 171419.59 | 495216.19 | 6.46 | 7.00 |
| 6. | Villiera | 552.80 | 846.54 | 2028.79 | 3106.80 | 20287.97 | 24854.46 | 193811.08 | 372816.84 | 4.52 | 4.87 |
| 7. | Rietfontein | 473.02 | 584.97 | 1735.98 | 2146.84 | 17359.88 | 17174.74 | 144401.63 | 257621.12 | 3.87 | 3.36 |
| 8. | Hatfield | 375.98 | 542.57 | 1379.87 | 1991.24 | 13798.70 | 15929.96 | 90933.43 | 238949.47 | 3.08 | 3.12 |
| 9. | Pretoria North | 372.49 | 478.67 | 1367.06 | 1756.73 | 13670.64 | 14053.85 | 90089.54 | 210807.76 | 3.05 | 2.75 |
| 10. | Waterkloof Ridge | 367.28 | 638.41 | 1347.94 | 2324.98 | 13479.44 | 18743.88 | 88829.53 | 281158.23 | 3.00 | 3.67 |
| 11. | Proclamation Hill | 352.15 | 506.95 | 1292.41 | 1860.52 | 12924.18 | 14884.21 | 85170.32 | 223263.12 | 2.88 | 2.91 |
| 12. | Pretoria West | 297.84 | 193.88 | 1093.08 | 711.55 | 10930.82 | 5692.44 | 72034.08 | 85386.59 | 2.44 | 1.20 |
| 13. | Muckleneuk | 290.64 | 400.85 | 1066.67 | 1471.13 | 10666.75 | 11769.07 | 70293.90 | 176536.00 | 2.38 | 2.30 |
| 14. | Lynnwood | 261.11 | 236.81 | 958.27 | 869.09 | 9582.73 | 6952.76 | 63150.16 | 104291.47 | 2.13 | 1.47 |
| 15. | Riviera | 239.76 | 591.95 | 879.92 | 2172.46 | 8799.28 | 17379.71 | 57987.20 | 260695.72 | 1.96 | 3.40 |
| 16. | Claremont | 230.64 | 251.89 | 846.45 | 921.86 | 8464.57 | 7374.93 | 55781.49 | 110623.94 | 1.88 | 1.56 |
| 17. | Lisdogan Park | 220.38 | 230.83 | 808.82 | 847.16 | 8088.20 | 6777.32 | 53301.21 | 101659.81 | 1.80 | 1.32 |
| 18. | Rietondale | 211.94 | 556.73 | 777.82 | 2043.20 | 7778.22 | 16345.62 | 51258.45 | 245184.30 | 1.73 | 3.2 |
| 19. | Colbyn | 194.43 | 335.31 | 713.58 | 1230.62 | 7135.80 | 9844.96 | 47024.92 | 147674.47 | 1.59 | 1.92 |
| 20. | Laudium | 191.18 | 197.34 | 701.64 | 724.23 | 7016.47 | 5793.92 | 46238.51 | 86908.77 | 1.56 | 1.22 |
| 21. | Annlin | 176.62 | 317.70 | 648.22 | 1165.98 | 6482.22 | 9327.86 | 42717.84 | 139918.02 | 1.44 | 1.82 |
| 22. | Menlo Park | 173.31 | 157.61 | 636.04 | 578.46 | 6360.49 | 4627.70 | 41915.60 | 69415.64 | 1.42 | 0.90 |
| 23. | Wes Park | 172.48 | 396.77 | 633.01 | 1456.15 | 6330.14 | 11649.27 | 41715.62 | 174739.09 | 1.41 | 2.28 |

| | Suburb | Total t C per suburb | | Total t $CO_2$eq per suburb | | US$ | | ZAR | | % of Total ZAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 24. | Valhalla | 155.68 | 203.39 | 571.35 | 746.45 | 5713.58 | 5971.68 | 37652.52 | 89575.16 | 1.27 | 1.26 |
| 25. | Wonderboom South | 132.01 | 213.59 | 484.49 | 783.88 | 4844.93 | 6271.09 | 31928.06 | 94066.41 | 1.08 | 1.22 |
| 26 | Eastwood | 129.20 | 104.13 | 474.16 | 382.17 | 4741.68 | 3057.42 | 31247.70 | 45861.38 | 1.05 | 0.59 |
| 27. | Pretoria Industrial | 117.62 | 175.17 | 431.67 | 642.88 | 4316.76 | 5143.06 | 28447.47 | 77145.90 | 0.96 | 1.00 |
| 28. | Niew Muckleneuk | 115.72 | 86.28 | 424.70 | 316.67 | 4247.03 | 2533.40 | 27987.93 | 38001.09 | 0.94 | 0.49 |
| 29. | Kwaggasrand | 109.05 | 209.25 | 400.21 | 767.95 | 4002.17 | 6143.62 | 26374.29 | 92154.34 | 0.89 | 1.20 |
| 30. | Ashlea Gardens | 107.49 | 161.06 | 394.49 | 591.10 | 3944.92 | 4728.87 | 25997.00 | 70933.16 | 0.88 | 0.92 |
| 31. | Eersterust | 100.60 | 295.18 | 369.21 | 1083.33 | 3692.11 | 8666.64 | 24330.99 | 129999.65 | 0.85 | 1.69 |
| 32. | Mountain View | 93.64 | 84.35 | 343.67 | 309.59 | 3436.76 | 2476.74 | 22648.28 | 37151.15 | 0.7 | 0.52 |
| 33. | Lukasrand | 80.04 | 112.39 | 293.75 | 412.49 | 2937.53 | 3300 | 19358.31 | 49499.99 | 0.65 | 0.64 |
| 34. | Eloffsdal | 77.39 | 73.36 | 284.04 | 269.26 | 2840.44 | 2154.09 | 18718.52 | 32311.46 | 0.63 | 0.42 |
| 35. | Pretoria Gardens | 67.44 | 61.00 | 247.52 | 223.88 | 2475.24 | 1791.08 | 16311.82 | 26866.23 | 0.55 | 0.35 |
| 36. | Watloo | 56.68 | 128.78 | 208.02 | 472.64 | 2080.27 | 3781.13 | 13708.95 | 56716.95 | 0.46 | 0.74 |
| 37. | Silverton | 55.08 | 112.64 | 202.14 | 413.41 | 2021.44 | 3307.35 | 13321.29 | 49610.30 | 0.45 | 0.66 |
| 38. | Garsfontein | 54.67 | 93.90 | 200.63 | 344.61 | 2006.39 | 2756.95 | 13222.09 | 41354.18 | 0.44 | 0.58 |
| 39. | Queenswood | 54.31 | 49.09 | 199.33 | 180.19 | 1993.31 | 1441.55 | 13135.92 | 21623.26 | 0.44 | 0.28 |
| 40. | Trevena | 53.11 | 71.59 | 194.91 | 262.76 | 1949.18 | 2102.09 | 12845.08 | 31531 | 0.43 | 0.41 |
| 41. | Constantia Park | 51.38 | 101.64 | 188.58 | 373.02 | 1885.88 | 2984.19 | 12427.97 | 44762.90 | 0.42 | 0.58 |
| 42. | Meyers Park | 48.85 | 18.72 | 179.29 | 68.73 | 1792.96 | 549.87 | 11815.62 | 8248.09 | 0.40 | 0.11 |
| 43. | Asiatic Bazaar | 47.79 | 34.89 | 175.39 | 128.06 | 1753.92 | 1024.54 | 11558.34 | 15368.09 | 0.39 | 0.21 |
| 44. | Sinoville | 45.35 | 84.64 | 166.46 | 310.63 | 1664.63 | 2485.07 | 10969.91 | 37276.05 | 0.37 | 0.48 |
| 45. | Salvokop | 40.15 | 23.25 | 147.38 | 85.35 | 1473.84 | 682.83 | 9712 | 10242.42 | 0.32 | 0.11 |
| 46. | Hillcrest | 33.85 | 55.92 | 124.26 | 205.25 | 1242.61 | 1642.00 | 8188.82 | 24630.02 | 0.27 | 0.32 |
| 47. | Attridgeville | 30.54 | 45.26 | 112.09 | 166.131 | 1120.98 | 1329.05 | 7387.29 | 19935.82 | 0.25 | 0.28 |
| 48. | Mamelodi | 28.54 | 101.96 | 104.77 | 374.22 | 1047.75 | 2993.79 | 6904.64 | 44906.91 | 0.23 | 0.58 |
| 49. | Kilner Park | 28.40 | 82.48 | 104.25 | 302.728 | 1042.51 | 2421.84 | 6870.12 | 36327.60 | 0.23 | 0.47 |

| | Suburb | Total t C per suburb | | Total t $CO_2$eq per suburb | | US$ | | ZAR | | % of Total ZAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 50. | Lynnwood Glen | 25.31 | 36.05 | 92.893 | 132.30 | 928.93 | 1058.47 | 6121.64 | 15877.15 | 0.20 | 0.20 |
| 51. | Erasmusrand | 24.69 | 44.49 | 90.61 | 163.29 | 906.18 | 1306.36 | 5971.72 | 19595.40 | 0.20 | 0.25 |
| 52. | Waterkloof Park | 24.09 | 68.77 | 88.43 | 252.42 | 884.32 | 2019.36 | 5827.70 | 30290.52 | 0.19 | 0.39 |
| 53. | Moreleta Park | 22.45 | 70.32 | 82.39 | 258.07 | 823.99 | 2064.63 | 5430.12 | 30969.42 | 0.18 | 0.43 |
| 54. | Clydesdale | 21.26 | 26.12 | 78.04 | 95.87 | 780.44 | 767.00 | 5143.09 | 11504.95 | 0.17 | 0.16 |
| 55. | Danville | 18.05 | 40.28 | 66.24 | 147.82 | 662.47 | 1182.63 | 4365.68 | 17739.58 | 0.14 | 0.23 |
| 56. | Waterkloof Glen | 17.82 | 40.63 | 65.41 | 149.14 | 654.15 | 1193.16 | 4310.88 | 17897.51 | 0.14 | 0.23 |
| 57. | Alphen Park | 15.82 | 31.35 | 58.07 | 115.07 | 580.70 | 920.60 | 3826.79 | 13809.01 | 0.13 | 0.11 |
| 58. | La Montagne | 10.04 | 18.92 | 36.87 | 69.46 | 368.74 | 555.76 | 2430.00 | 8336.33 | 0.08 | 0.13 |
| 59. | Faerie Glen | 8.88 | 62.41 | 32.62 | 229.06 | 326.23 | 1832.51 | 2149.86 | 27487.69 | 0.07 | 0.38 |
| 60. | Maroelana | 7.61 | 18.49 | 27.96 | 67.88 | 279.63 | 543.11 | 1842.73 | 8146.77 | 0.06 | 0.10 |
| 61. | Lynnwood Ridge | 6.85 | 34.52 | 25.16 | 126.70 | 251.61 | 1013.66 | 1658.10 | 15205.00 | 0.05 | 0.19 |
| 62. | Jan Niemand Park | 5.37 | 12.64 | 19.72 | 46.42 | 197.28 | 371.37 | 1300.05 | 5570.48 | 0.04 | 0.007 |
| 63. | Hazelwood | 5.19 | 20.54 | 19.07 | 75.39 | 190.72 | 603.18 | 1256.82 | 9047.63 | 0.04 | 0.12 |
| 64. | Montana | 4.19 | 35.30 | 15.39 | 129.57 | 153.95 | 1036.58 | 1014.56 | 15548.83 | 0.03 | 0.20 |
| 65. | Saulsville | 2.90 | 34.80 | 10.64 | 127.74 | 106.45 | 1021.94 | 701.49 | 15329.17 | 0.02 | 0.21 |
| 66. | Philip Nel Park | 2.18 | 31.35 | 8.00 | 115.07 | 80.07 | 920.60 | 527.65 | 13809.01 | 0.01 | 0.18 |
| 67. | Elardus Park | 2.00 | 31.02 | 7.36 | 113.87 | 73.64 | 911.02 | 485.29 | 13665.41 | 0.01 | 0.17 |
| 68. | Erasmuskloof | 1.62 | 16.11 | 5.96 | 59.15 | 59.63 | 473.22 | 392.95 | 7098.23 | 0.01 | 0.10 |
| 69. | Mayville | 1.15 | 8.25 | 4.24 | 30.27 | 42.41 | 242.23 | 279.51 | 3633.52 | 0.009 | 0.05 |
| 70. | Hestea Park | 0.91 | 75.11 | 3.35 | 275.66 | 33.52 | 2205.34 | 220.87 | 33080.17 | 0.007 | 0.46 |
| 71. | Newlands | 0.34 | 12.41 | 1.27 | 45.56 | 12.71 | 364.50 | 83.77 | 5467.44 | 0.003 | 0.07 |
| 72. | Wingate Park | 0.34 | 15.57 | 1.26 | 57.16 | 12.61 | 457.30 | 83.10 | 6859.55 | 0.003 | 0.09 |

Table 4.14 shows the suburb name, the Total Carbon (tonne), the Total Carbon Dioxide Equivalent (tonne) per suburb, the associated Total Carbon Dioxide Equivalent Rand and US Dollar values. This data is reflected in *descending* order for 2019.

| | Suburb | Total t C per suburb | | Total t $CO_2$eq per suburb | | US$ | | ZAR | | % of Total ZAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 1. | Pretoria Central | 1379.03 | 1380.68 | 5061.06 | 5067.12 | 50610.67 | 40537.03 | 333524.29 | 608055.41 | 11.29 | 8.59 |
| 2. | Arcadia | 708.77 | 1124.49 | 2601.20 | 4126.80 | 26012.08 | 33014.44 | 171419.59 | 495216.19 | 5.80 | 7.00 |
| 3 | Brooklyn | 1195.30 | 1048.53 | 4386.93 | 3848.11 | 43869.39 | 30784.96 | 289099.26 | 461774.31 | 9.79 | 6.52 |
| 4. | Villiera | 552.80 | 846.54 | 2028.79 | 3106.80 | 20287.97 | 24854.46 | 133697.70 | 372816.84 | 4.52 | 4.87 |
| 5. | Waterkloof | 801.35 | 797.76 | 2940.98 | 2927.80 | 29409.88 | 23422.42 | 193811.08 | 351336.24 | 6.56 | 4.58 |
| 6. | Sunnyside | 788.65 | 724.21 | 2894.34 | 2657.87 | 28943.49 | 21263.03 | 190737.60 | 318945.40 | 6.46 | 4.50 |
| 7. | Waterkloof Ridge | 367.28 | 638.41 | 1347.94 | 2324.98 | 13479.44 | 18743.88 | 88829.53 | 281158.23 | 3.00 | 3.67 |
| 8. | Riviera | 239.76 | 591.95 | 879.92 | 2172.46 | 8799.28 | 17379.71 | 57987.29 | 260695.72 | 1.96 | 3.40 |
| 9. | Rietfontein | 473.02 | 584.97 | 1735.98 | 2146.84 | 17359.88 | 17174.74 | 144401.63 | 257621.12 | 3.87 | 3.36 |
| 10. | Rietondale | 211.94 | 556.73 | 777.82 | 2043.20 | 7778.22 | 16345.62 | 51258.45 | 245184.30 | 1.73 | 3.2 |
| 11. | Hatfield | 375.98 | 542.57 | 1379.87 | 1991.24 | 13798.70 | 15929.96 | 90933.43 | 238949.47 | 3.08 | 3.12 |
| 12. | Proclamation Hill | 352.15 | 506.95 | 1292.41 | 1860.52 | 12924.18 | 14884.21 | 85170.32 | 223263.12 | 2.88 | 2.91 |
| 13. | Pretoria North | 372.49 | 478.67 | 1367.06 | 1756.73 | 13670.64 | 14053.85 | 90089.54 | 210807.76 | 3.05 | 2.75 |
| 14. | Muckleneuk | 290.64 | 400.85 | 1066.67 | 1471.13 | 10666.67 | 11769.07 | 70293.90 | 176536.00 | 2.38 | 2.30 |
| 15. | Wespark | 172.48 | 396.77 | 633.01 | 1456.15 | 6330.14 | 11649.27 | 41715.62 | 174739.09 | 1.41 | 2.28 |
| 16. | Colbyn | 194.43 | 335.31 | 713.58 | 1230.62 | 7135.80 | 9844.96 | 47024.92 | 147674.47 | 1.59 | 1.92 |
| 17. | Annlin | 176.62 | 317.70 | 648.22 | 1165.98 | 6482.22 | 9327.86 | 42717.84 | 139918.02 | 1.44 | 1.82 |
| 18. | Eersterust | 100.60 | 295.18 | 369.21 | 1083.33 | 3692.11 | 8666.64 | 24330.99 | 129999.65 | 0.85 | 1.69 |
| 19. | Laudium | 191.18 | 251.66 | 701.64 | 923.59 | 7016.47 | 7388.74 | 46238.51 | 110831.21 | 1.56 | 1.44 |
| 20. | Claremont | 230.64 | 251.18 | 846.45 | 921.86 | 8464.57 | 7374.93 | 55781.49 | 110623.94 | 1.88 | 1.56 |
| 21. | Lynnwood | 261.11 | 236.81 | 958.27 | 869.09 | 9582.73 | 6952.76 | 63150.16 | 104291.47 | 2.13 | 1.47 |
| 22. | Lisdogan Park | 220.38 | 230.83 | 808.82 | 847.16 | 8088.20 | 6777.32 | 53301.21 | 101659.81 | 1.80 | 1.32 |
| 23. | Wonderboom South | 132.01 | 213.59 | 484.49 | 783.88 | 4844.93 | 6271.09 | 31928.06 | 94066.41 | 1.08 | 1.22 |

| | Suburb | Total t C per suburb | | Total t $CO_2$eq per suburb | | US$ | | ZAR | | % of Total ZAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 24. | Kwaggasrand | 109.05 | 209.25 | 400.21 | 767.95 | 4002.17 | 6143.62 | 26374.29 | 92154.34 | 0.89 | 1.20 |
| 25. | Valhalla | 155.68 | 203.39 | 571.35 | 746.45 | 5713.58 | 5971.68 | 37652.52 | 89575.16 | 1.27 | 1.26 |
| 26. | Pretoria West | 297.84 | 193.88 | 1093.08 | 711.55 | 10930.82 | 5692.44 | 72034.08 | 85386.59 | 2.44 | 1.20 |
| 27. | Pretoria Industrial | 117.62 | 175.17 | 431.67 | 642.88 | 4316.76 | 5143.06 | 28447.47 | 77145.90 | 0.96 | 1.00 |
| 28. | Menlo Park | 173.31 | 157.61 | 636.04 | 578.46 | 6360.49 | 4627.70 | 41915.60 | 69415.64 | 1.42 | 0.90 |
| 29. | Watloo | 56.68 | 128.78 | 2018.02 | 472.64 | 2080.27 | 3781.13 | 13708.95 | 56716.95 | 0.46 | 0.74 |
| 30. | Ashlea Gardens | 107.49 | 126.55 | 394.49 | 464.47 | 3944.92 | 3715.77 | 25997.00 | 55736.20 | 0.88 | 0.78 |
| 31. | Silverton | 55.08 | 112.64 | 202.14 | 413.41 | 2021.44 | 3307.35 | 13321.29 | 49610.30 | 0.45 | 0.64 |
| 32. | Lukasrand | 80.04 | 112.39 | 293.75 | 412.49 | 2937.53 | 3300 | 19358.31 | 49499.99 | 0.65 | 0.64 |
| 33. | Eastwood | 129.20 | 104.13 | 474.16 | 382.17 | 4741.68 | 3057.42 | 31247.70 | 45861.38 | 1.05 | 0.59 |
| 34. | Mamelodi | 28.54 | 101.96 | 104.77 | 374.22 | 1047.75 | 2993.79 | 6904.64 | 44906.91 | 0.23 | 0.58 |
| 35. | Constantia Park | 51.38 | 101.64 | 188.58 | 373.02 | 1885.88 | 2984.19 | 12427.97 | 44762.90 | 0.42 | 0.58 |
| 36. | Garsfontein | 54.67 | 93.90 | 200.63 | 344.61 | 2006.39 | 2756.95 | 13222.09 | 41354.18 | 0.44 | 0.58 |
| 37. | Nieuw Muckleneuk | 115.72 | 86.28 | 424.70 | 316.67 | 4247.03 | 2533.40 | 27987.93 | 38001.09 | 0.94 | 0.49 |
| 38. | Sinoville | 45.35 | 84.64 | 166.46 | 310.63 | 1664.63 | 2485.07 | 10969.91 | 37276.05 | 0.37 | 0.48 |
| 39. | Mountain View | 93.64 | 84.35 | 343.67 | 309.59 | 3436.76 | 2476.74 | 22648.28 | 37151.15 | 0.7 | 0.52 |
| 40. | Kilner Park | 28.40 | 82.48 | 104.25 | 302.72 | 1042.51 | 2421.84 | 6870.12 | 36327.60 | 0.23 | 0.47 |
| 41. | Hestea Park | 0.91 | 75.11 | 3.35 | 275.66 | 33.52 | 2205.34 | 220.87 | 33080.17 | 0.007 | 0.46 |
| 42. | Eloffsdal | 77.39 | 73.36 | 284.04 | 269.26 | 2840.44 | 2154.09 | 18718.52 | 32311.46 | 0.63 | 0.42 |
| 43. | Trevena | 53.11 | 71.59 | 194.91 | 262.76 | 1949.18 | 2102.09 | 12845.08 | 31531 | 0.43 | 0.41 |
| 44. | Moreleta Park | 22.45 | 70.32 | 82.39 | 258.07 | 823.99 | 2064.63 | 5430.12 | 30969.42 | 0.18 | 0.43 |
| 45. | Waterkloof Park | 24.09 | 68.77 | 88.43 | 262.42 | 884.32 | 2019.36 | 5827.70 | 30290.52 | 0.19 | 0.39 |
| 46 | Faerie Glen | 8.88 | 62.41 | 32.62 | 229.06 | 326.23 | 1832.51 | 2149.86 | 27487.69 | 0.07 | 0.38 |
| 47. | Pretoria Gardens | 67.44 | 61.00 | 247.52 | 223.88 | 2475.24 | 1791.08 | 16311.82 | 26866.23 | 0.55 | 0.35 |
| 48. | Hillcrest | 33.85 | 55.92 | 124.26 | 205.25 | 1242.61 | 1642.00 | 8188.82 | 24630.02 | 0.27 | 0.32 |
| 49. | Queenswood | 54.31 | 49.09 | 199.33 | 180.19 | 1993.31 | 1441.55 | 13135.92 | 21623.26 | 0.44 | 0.28 |

| | Suburb | Total t C per suburb | | Total t $CO_2$eq per suburb | | US$ | | ZAR | | % of Total ZAR | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 | 2004 | 2019 |
| 50. | Attridgeville | 30.54 | 45.26 | 11209 | 166.13 | 1120.98 | 1329.05 | 7387.29 | 19935.82 | 0.25 | 0.28 |
| 51. | Erasmusrand | 24.69 | 44.49 | 90.61 | 163.29 | 906.18 | 1306.36 | 5971.72 | 19595.40 | 0.20 | 0.25 |
| 52. | Waterkloof Glen | 17.82 | 40.63 | 65.41 | 149.14 | 654.15 | 1193.16 | 4310.88 | 17897.51 | 0.14 | 0.23 |
| 53. | Danville | 18.05 | 40.28 | 66.24 | 147.82 | 662.47 | 1182.63 | 4365.68 | 17739.58 | 0.14 | 0.23 |
| 54. | Lynnwood Glen | 25.31 | 36.05 | 92.89 | 132.30 | 928.93 | 1058.47 | 6121.64 | 15877.15 | 0.20 | 0.20 |
| 55. | Montana | 4.19 | 35.30 | 15.39 | 129.57 | 153.95 | 1036.58 | 1014.56 | 15548.83 | 0.03 | 0.20 |
| 56. | Saulsville | 2.90 | 34.80 | 10.64 | 127.74 | 106.45 | 1021.94 | 701.49 | 15329.17 | 0.02 | 0.21 |
| 57. | Asiatic Bazaar | 47.79 | 34.89 | 175.39 | 128.06 | 1753.92 | 1024.54 | 11558.34 | 15368.09 | 0.39 | 0.21 |
| 58. | Lynnwood Ridge | 6.85 | 34.62 | 25.16 | 126.70 | 251.61 | 1013.66 | 1658.10 | 15205.00 | 0.05 | 0.19 |
| 59. | Alphen Park | 15.83 | 31.35 | 58.07 | 115.07 | 580.70 | 920.60 | 3826.79 | 13809.01 | 0.13 | 0.18 |
| 60. | Elardus Park | 2.00 | 31.02 | 7.36 | 113.87 | 73.64 | 911.02 | 485.29 | 13665.41 | 0.01 | 0.17 |
| 61. | Salvokop | 40.15 | 30.16 | 147.38 | 110.72 | 1473.84 | 885.76 | 9712 | 13286.53 | 0.32 | 0.17 |
| 62. | Hazelwood | 5.19 | 29.97 | 19.07 | 110.00 | 190.72 | 880.01 | 1256.82 | 13200.17 | 0.04 | 0.17 |
| 63. | Clydesdale | 21.26 | 26.12 | 78.04 | 95.87 | 780.44 | 767.00 | 5143.09 | 11504.95 | 0.17 | 0.16 |
| 64. | La Montagne | 10.04 | 18.92 | 36.87 | 69.46 | 368.74 | 555.76 | 2430.00 | 8336.33 | 0.08 | 0.11 |
| 65. | Meyers Park | 48.85 | 18.72 | 179.29 | 68.73 | 1792.96 | 549.87 | 11815.62 | 8248.09 | 0.40 | 0.11 |
| 66.. | Maroelana | 7.61 | 18.49 | 27.96 | 67.88 | 279.63 | 543.11 | 1842.73 | 8146.77 | 0.06 | 0.10 |
| 67. | Erasmuskloof | 1.62 | 16.11 | 5.96 | 59.15 | 59.63 | 473.22 | 392.95 | 7098.23 | 0.01 | 0.10 |
| 68. | Philip Nel Park | 2.18 | 16.09 | 8.00 | 59.06 | 80.07 | 472.49 | 527.65 | 7087.46 | 0.01 | 0.09 |
| 69. | Wingate Park | 0.34 | 15.57 | 1.261 | 57.16 | 12.61 | 457.30 | 83.10 | 6859.55 | 0.003 | 0.09 |
| 70. | Jan Niemand Park | 5.37 | 12.64 | 19.72 | 46.42 | 197.28 | 371.37 | 1300.05 | 5570.48 | 0.04 | 0.07 |
| 71 | Newlands | 0.34 | 12.44 | 1.27 | 45.56 | 12.71 | 364.50 | 83.77 | 5467.44 | 0.003 | 0.07 |
| 72. | Mayville | 1.15 | 8.25 | 4.24 | 30.27 | 42.41 | 242.23 | 279.51 | 3633.52 | 0.009 | 0.05 |

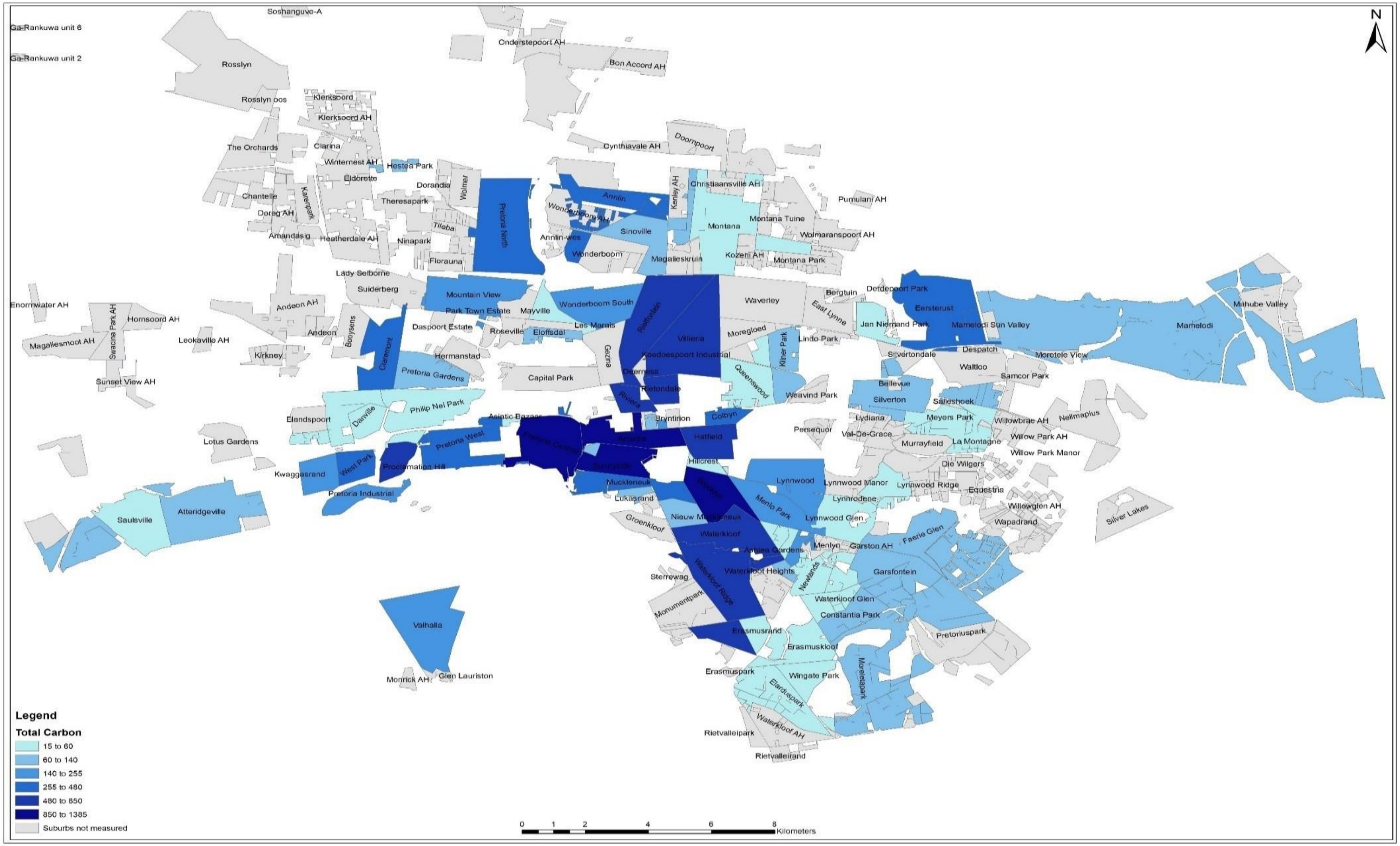


Figure 4.12: Map showing the Total Carbon per suburb in 2019.

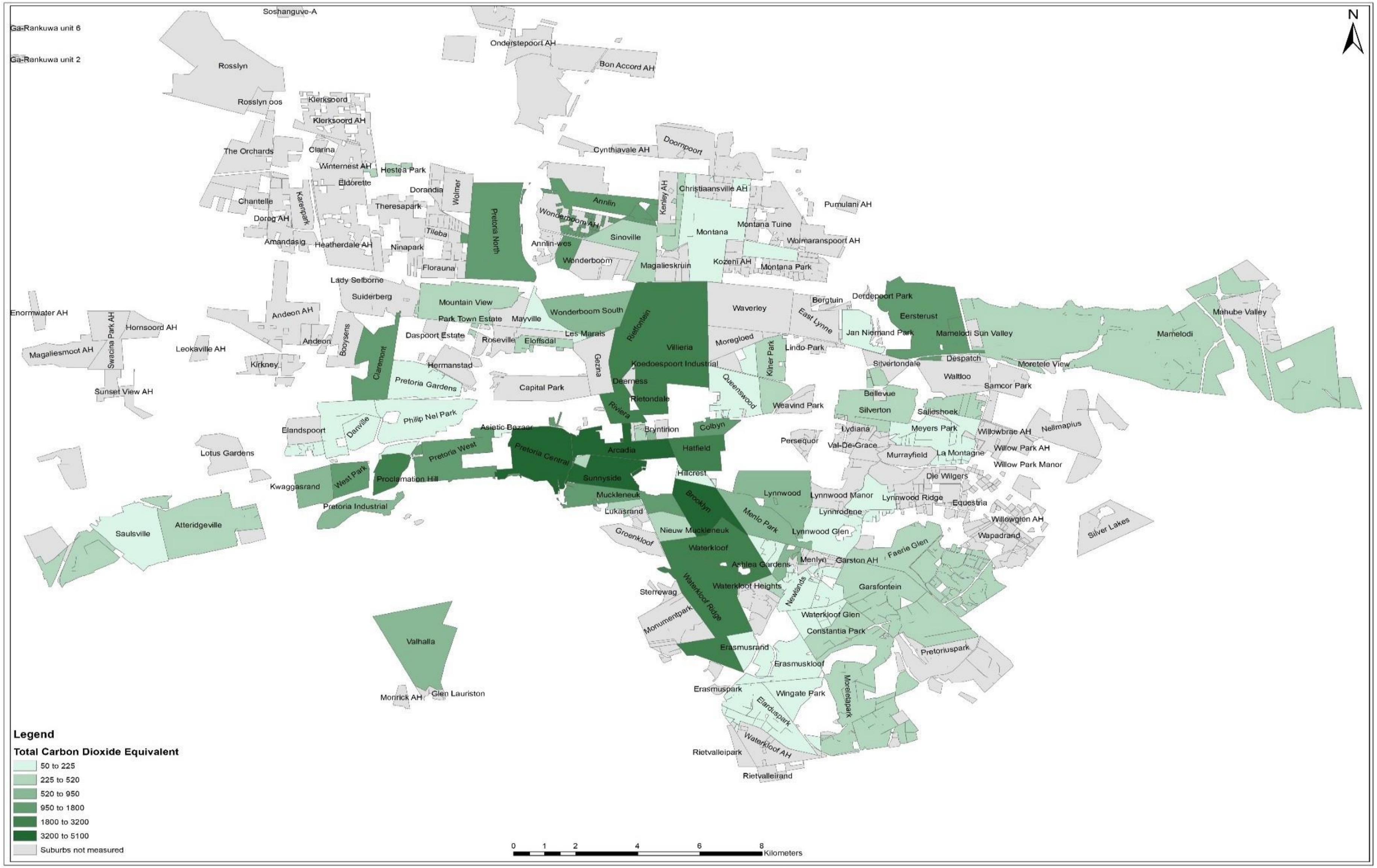


Figure 4.13: Map of the Total Carbon Dioxide Equivalent per suburb in 2019.

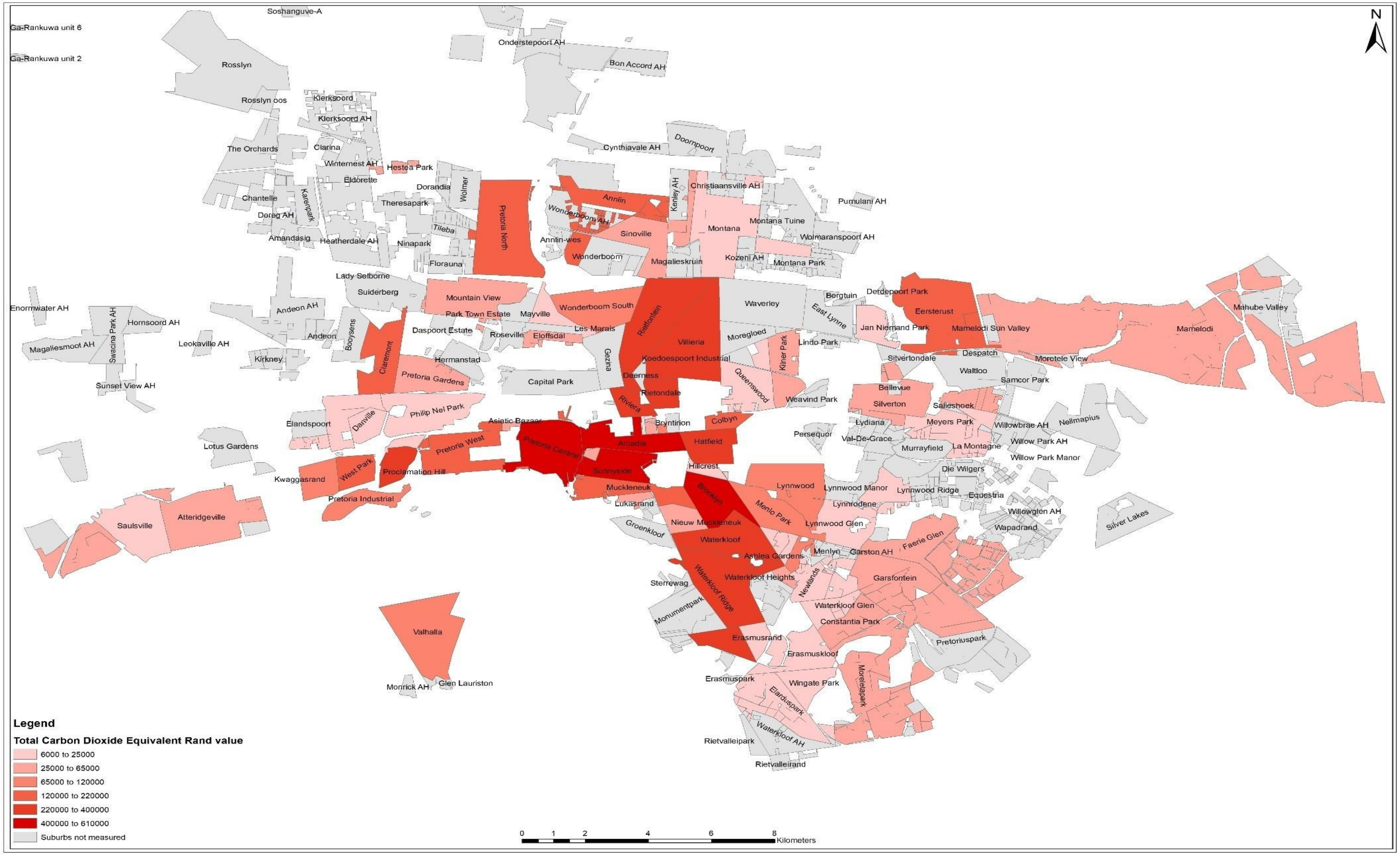


Figure 4.14: Map of the Total Carbon Dioxide Equivalent Carbon Tax Rand value per suburb in 2019

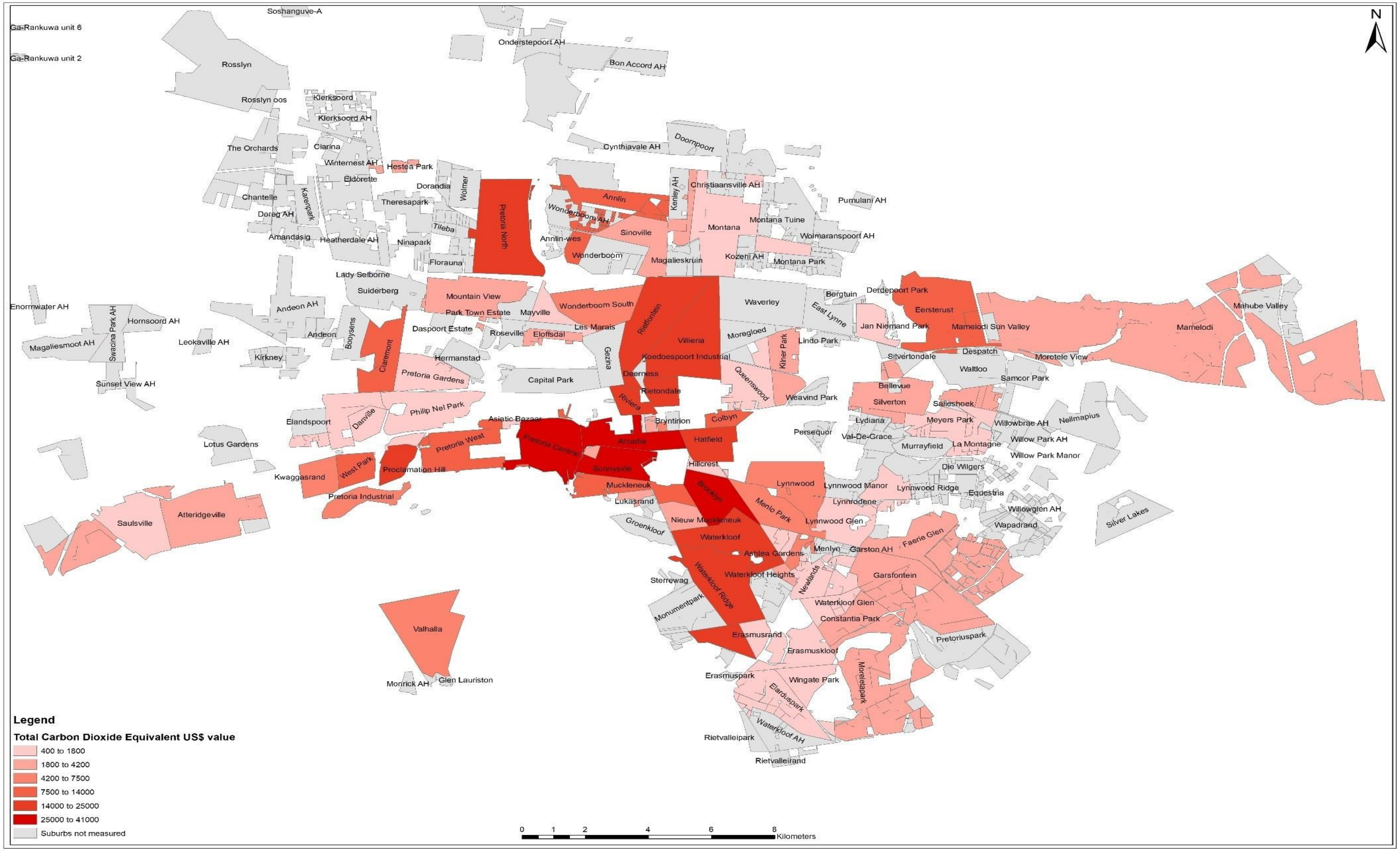


Figure 4.15: Map of the Total Carbon Dioxide Equivalent US Dollar values per suburb in 2019.

### 4.2.6. Difference in the Total Carbon per suburb and the associated monetary values.

Table 4.15 Table 4.14 shows the difference in Total Carbon, Total C, US$ Dollar and Rands between 2004 and 2019. This study used the South African National Treasury's Carbon Tax Bill which states that 1 tonne of Carbon is equal to R120. This study used the exchange rate, relevant to the time of study, of US$1 being equal to R15.00 (businesstech.co.za, 2018). Therefore, to calculate the US$ value the Carbon Tax Rand value was divided by the exchange rate value above of US$1 Is equal to R15.

Figure 4.19 compares the Total above ground and below ground Carbon in 2004 and 2019. Suburbs illustrated in the lightest colour have the highest differences in the Total Carbon.
The highest differences occurred in Arcadia, Riviera, Rietondale and Villiera with estimated Total Carbon increases of 415.59 t C, 352.19 t C, 344.79 t C and 293.74 t C, respectively. Suburbs that saw a decrease in the Total Carbon sequestrated since the baseline study were Meyers Park, Sunnyside, Pretoria West and Brooklyn, respectively. These suburbs saw an estimated decrease of the Total Carbon sequestrated of - 30.12 t C, - 64.43t C, - 103.95 t C and - 146.81 t C respectively since 2004.

Figure 4.21 compares the Total above ground and below ground Carbon Dioxide Equivalent in 2004 and 2019. Suburbs illustrated in the lightest colour have the highest differences in the Total Carbon colour Dioxide Equivalent. The highest differences occurred in Arcadia, Riviera, Rietondale and Villiera with estimated Total Carbon Dioxide Equivalent increases of
1525.60 t $CO_2$ eq, 1292.54 t $CO_2$ eq, 1265.88 t $CO_2$ eq and 1078.07 t $CO_2$ eq, respectively. Suburbs that saw a decrease in the Total Carbon sequestrated since the baseline study were Sunnyside, Pretoria West, Brooklyn and Watloo, respectively. These suburbs saw an estimated decrease of the Total Carbon sequestrated of - 236.46 t $CO_2$ eq, - 381.52 t $CO_2$ eq, - 538.81 t $CO_2$ eq and - 1545.38 t $CO_2$ eq respectively since 2004

Figure 4.23 compares the Total Carbon Dioxide Equivalent US Dollar amounts in 2004 and 2019. Suburbs illustrated in the lightest colour have the highest US Dollar differences. The highest differences occurred in Riviera, Rietondale, Arcadia and Wespark with estimated US Dollar increases of US$ 8580.43, US$ 8567.40, US$

7002.33 and US$ 5319.13, respectively. Suburbs that saw the highest US Dollar decrease were Waterkloof, Sunnyside, Pretoria Central and Brooklyn, respectively. These suburbs saw an estimated decrease of US$ - 5987.46, US$ - 7680.46, US$ - 10073.60 and US$ - 13084.40 respectively since 2004

Figure 4.25 compares the Total Carbon Dioxide Equivalent Rand amounts in 2004 and 2019. Suburbs illustrated in the lightest colour have the highest Rand differences. The highest differences occurred in Arcadia, Pretoria Central, Villiera and Riviera with estimated Rand increases of R323 796.60, R274 531.10, R239 119.10 and R202 708.40, respectively. Suburbs that saw the lowest Rand increases were Asiatic Bazaar, Mayville and Salvokop, respectively. These suburbs saw an estimated increase of R3809.75, R3354.01 and R529.83 respectively since 2004. Meyers Park had the highest decrease with an estimated Rand value decrease of -R3567.53 since 2004.

Table 4.15 shows the difference in Total Carbon, Total Carbon Dioxide Equivalent and the associated Total Carbon Dioxide Equivalent US Dollar and Rand values between 2004 and 2019.

| | **Suburb Name** | **Difference in Total Carbon** | **Difference in Total $CO_2$ eq** | **Difference in US$ amount of the Total $CO_2$ eq** | **Difference in ZAR amount of the Total $CO_2$ eq** |
|---|---|---|---|---|---|
| 1 | Alphen Park | 15.53 | 57.00 | 339.90 | 9982.22 |
| 2 | Annlin | 141.08 | 517.76 | 2845.65 | 97200.18 |
| 3 | Arcadia | 415.69 | 1525.60 | 7002.33 | 323796.60 |
| 4 | Asiatic Bazaar | -12.89 | -47.32 | -729.38 | 3809.75 |
| 5 | Ashlea Gardens | 19.06 | 69.98 | 229.15 | 29739.60 |
| 6 | Atteridgeville | 14.72 | 54.04 | 208.07 | 12548.53 |
| 7 | Brooklyn | -146.81 | -538.81 | -13084.43 | 172675.08 |
| 8 | Claremont | 20.54 | 75.41 | -1089.64 | 54842.45 |
| 9 | Clydesdale | 4.86 | 17.83 | -13.44 | 6361.86 |
| 10 | Colbyn | 140.88 | 517.04 | 2709.16 | 100649.55 |
| 11 | Constantia Park | 50.26 | 184.44 | 1098.31 | 32334.93 |
| 12 | Danville | 22.23 | 81.58 | 520.17 | 13373.90 |
| 13 | Eastwood | -25.06 | -91.98 | -1684.25 | 14613.68 |
| 14 | Eersterust | 194.58 | 714.12 | 4974.53 | 105668.66 |
| 15 | Elardus Park | 29.02 | 106.51 | 837.39 | 13180.12 |
| 16 | Eloffsdal | -4.02 | -14.77 | -686.34 | 13592.94 |
| 17 | Erasmusrand | 19.80 | 72.68 | 400.18 | 13623.68 |
| 18 | Erasmuskloof | 14.49 | 53.19 | 413.59 | 6705.28 |
| 19 | Faerie Glen | 53.52 | 196.44 | 1506.28 | 25337.83 |
| 20 | Garsfontein | 39.23 | 143.98 | 750.56 | 28132.09 |
| 21 | Hatfield | 166.59 | 611.37 | 2131.26 | 148016.04 |
| 22 | Hazelwood | 15.34 | 56.32 | 412.46 | 7790.81 |
| 23 | Hestea Park | 74.20 | 272.31 | 2171.82 | 32859.30 |
| 24 | Hillcrest | 22.07 | 80.99 | 399.39 | 16441.20 |
| 25 | Jan Niemand Park | 7.27 | 26.70 | 174.09 | 4270.43 |
| 26 | Kilner Park | 54.08 | 198.48 | 1379.33 | 29457.48 |
| 27 | Kwaggasrand | 100.20 | 367.74 | 2141.45 | 65780.05 |
| 28 | La Montagne | 8.88 | 32.59 | 187.02 | 5906.33 |

| | Suburb Name | Difference in Total Carbon | Difference in Total $CO_2$ eq | Difference in US$ amount of the Total $CO_2$ eq | Difference in ZAR amount of the Total $CO_2$ eq |
|---|---|---|---|---|---|
| 29 | Laudium | 6.16 | 22.59 | 1222.55 | 40670.26 |
| 30 | Lisdogan Park | 10.45 | 38.34 | 1310.88 | 48358.60 |
| 31 | Lukasrand | 32.35 | 118.75 | 362.47 | 30141.68 |
| 32 | Lynnwood | -24.29 | -89.17 | 2629.97 | 41141.31 |
| 33 | Lynnwood Glen | 10.74 | 39.41 | 129.55 | 9755.51 |
| 34 | Lynnwood Ridge | 27.66 | 101.54 | 762.06 | 13546.90 |
| 35 | Mamelodi | 73.42 | 269.45 | 1946.04 | 38002.27 |
| 36 | Maroelana | 10.87 | 39.92 | 263.49 | 6304.04 |
| 37 | Mayville | 7.10 | 26.03 | 199.82 | 3354.01 |
| 38 | Menlo Park | -15.69 | -57.57 | -1732.78 | 27500.04 |
| 39 | Meyers Park | -30.12 | -110.55 | -1243.09 | -3567.53 |
| 40 | Montana | 31.11 | 114.18 | 882.64 | 14534.27 |
| 41 | Moreleta Park | 47.87 | 175.68 | 1240.64 | 25539.30 |
| 42 | Mountain View | -9.28 | -34.07 | -960 | 14502.87 |
| 43 | Muckleneuk | 110.21 | 404.46 | 1102.40 | 106242.10 |
| 44 | Newlands | 12.06 | 44.29 | 351.79 | 5383.67 |
| 45 | Nieuw Muckleneuk | -29.43 | 108.02 | -1713.62 | 10013.16 |
| 46 | Philip Nel Park | 13.91 | 51.05 | 392.43 | 6559.81 |
| 47 | Pretoria Central | 1.65 | 6.06 | -10073.64 | 274531.12 |
| 48 | Pretoria Gardens | -6.43 | -23.63 | 684.16 | 10554.41 |
| 49 | Pretoria Industrial | 57.55 | 211.21 | 826.30 | 48698.43 |
| 50 | Pretoria North | 106.18 | 389.67 | 383.21 | 120718.22 |
| 51 | Pretoria West | -103.95 | -381.52 | -5238.38 | 13352 |
| 52 | Proclamation Hill | 154.79 | 568.11 | 1960.03 | 138092.80 |
| 53 | Queenswood | -5.21 | -19.13 | -551.76 | 8487.34 |
| 54 | Rietfontein | 111.95 | 410.86 | -185.14 | 113.219 |
| 55 | Rietondale | 344.79 | 1265.38 | 8567.40 | 193925.85 |
| 56 | Riviera | 352 | 1292.54 | 8580.43 | 202708.43 |
| 57 | Saulsville | 31.90 | 117.09 | 915.49 | 14627.68 |
| 58 | Salvokop | -16.89 | -62.02 | -791.01 | 529.83 |
| 59 | Silverton | 57.56 | 211.27 | 1285.91 | 36289.01 |
| 60 | Sinoville | 39.29 | 144.17 | 820.44 | 26306.14 |

| | Suburb Name | Difference in Total Carbon | Difference in Total $CO_2$ eq | Difference in US$ amount of the Total $CO_2$ eq | Difference in ZAR amount of the Total $CO_2$ eq |
|---|---|---|---|---|---|
| 61 | Sunnyside | -64.43 | -236.46 | -7680.46 | 128207.80 |
| 62 | Trevena | 18.48 | 67.85 | 152.91 | 186686.31 |
| 63 | Valhalla | 47.71 | 175.10 | 258.10 | 51922.64 |
| 64 | Villiera | 293.74 | 1078.01 | 4566.49 | 239119.14 |
| 65 | Waterkloof | -3.59 | -13.17 | -5987.46 | 157525.16 |
| 66 | Waterkloof Glen | 22.81 | 83.73 | 539.02 | 13586.63 |
| 67 | Waterkloof Park | 44.68 | 163.99 | 1135.05 | 24462.82 |
| 68 | Waterkloof Ridge | 271.12 | 995.04 | 5264.44 | 192328.70 |
| 69 | Wespark | 224.29 | 823.14 | 5319.13 | 133023.47 |
| 70 | Watloo | 72.10 | -1545.38 | 1700.86 | 43008.00 |
| 71 | Wingate Park | 15.23 | 55.90 | 444.69 | 6776.45 |
| 72 | Wonderboom South | 81.58 | 299 | 1426.16 | 62138.35 |

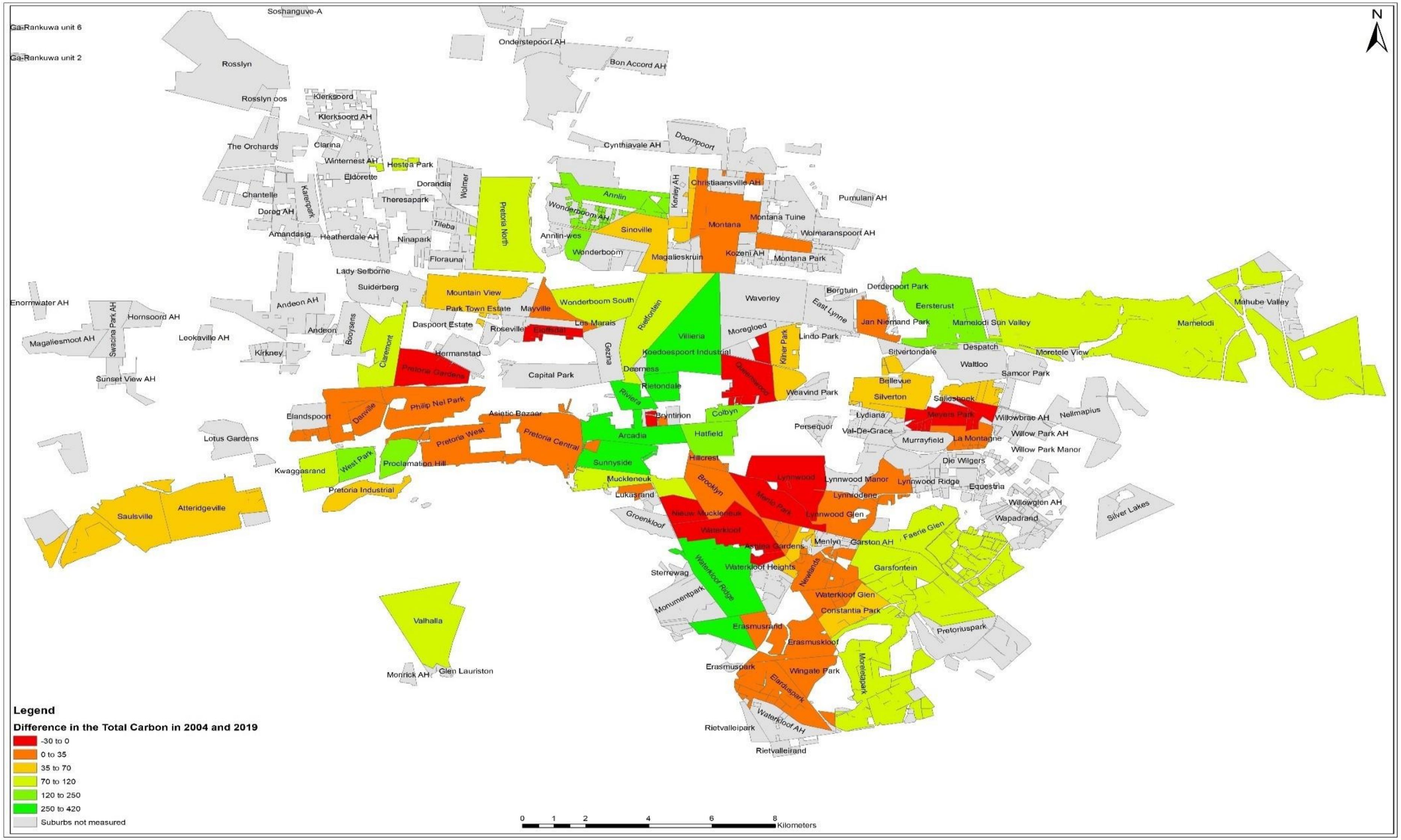


Figure 4.16: Map comparing the Total Carbon (tonnes) per suburb in 2004 and 2019.

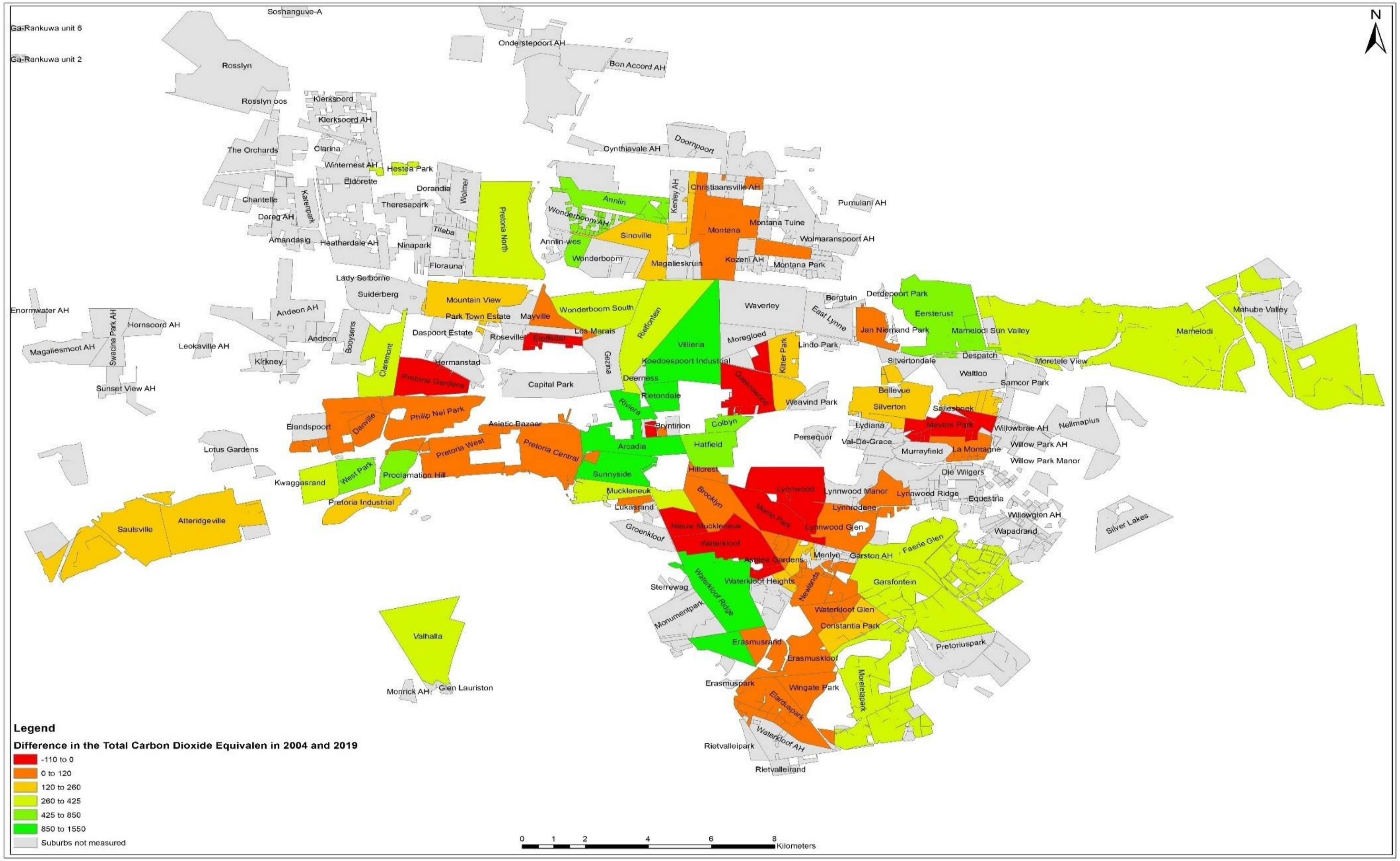


Figure 4.17: Map comparing the Total Carbon Dioxide Equivalent (tonnes) per suburb in 2004 and 2019.

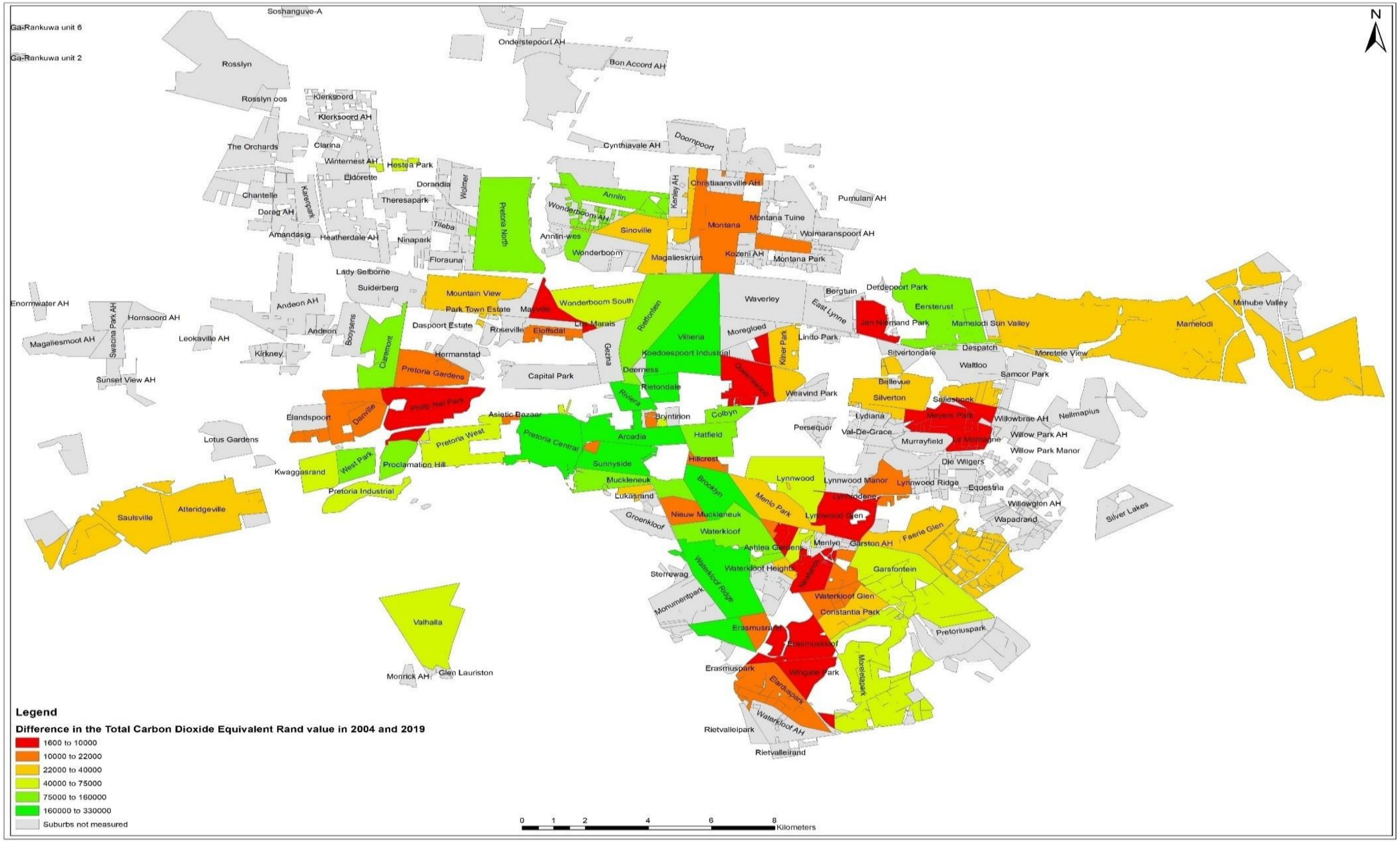


Figure 4.18: Map comparing the Total Carbon Equivalent (tonnes) Carbon Tax Rand value per suburb in 2004 and 2019.

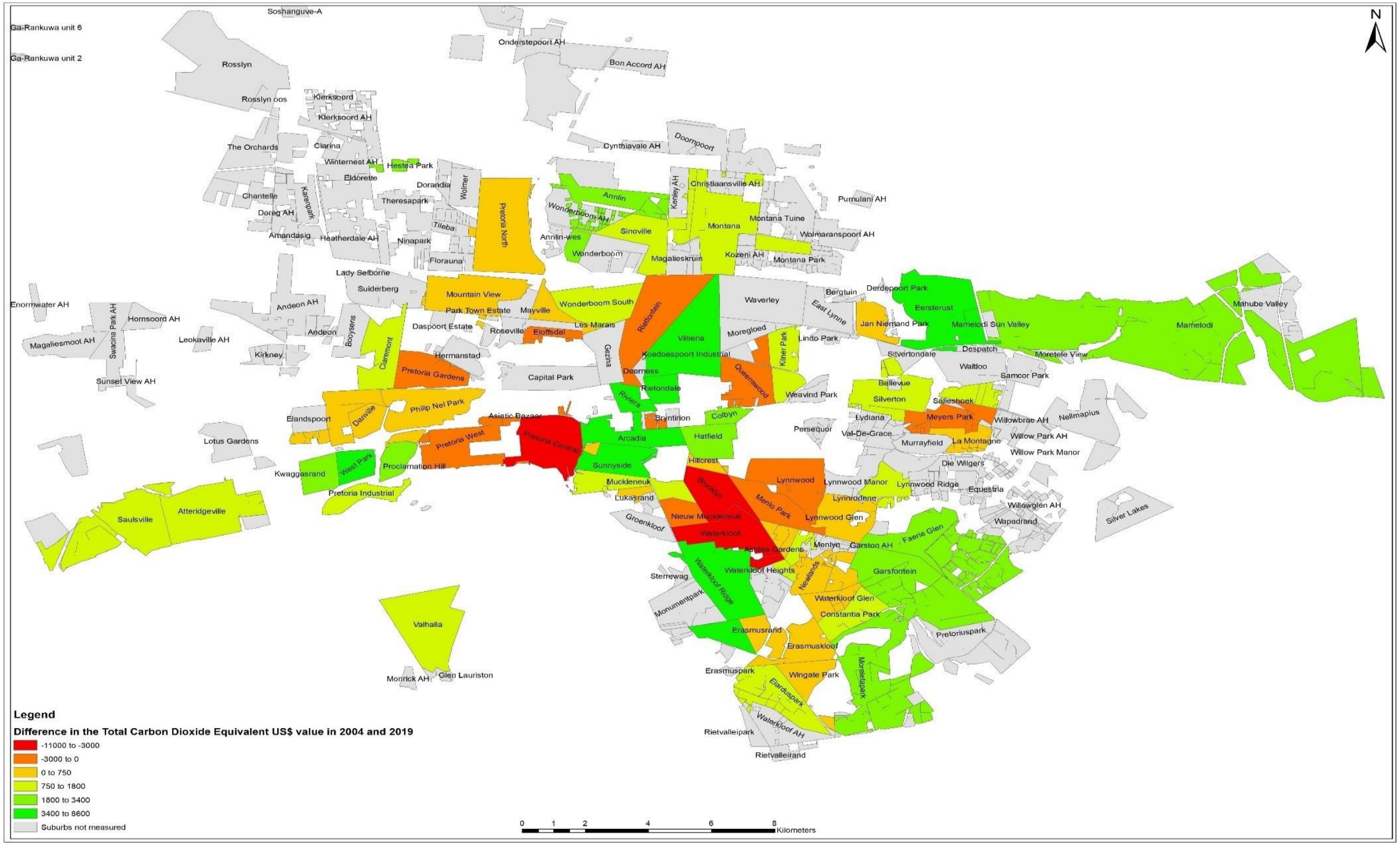


Figure 4.19: Map comparing the Total Carbon Dioxide Equivalent US Dollar values per suburb in 2004 and 2019.

### 4.2.7. Growth Environment

The following tables and graphs describe the circumstances in which the Jacaranda street trees are growing. This was done in order to determine any threats to the growth.

Out of 1540 Jacaranda street trees measured in this study. 997 (64.7%) trees had no pests or disease, 264 (17.14%) trees had termites, 225 had ants (14.61%) and 36 (2.33%) trees had both termites and ants. 13 (0.84%) trees had stranglers, 3 (0.19%) trees had both termites and ivy whilst 1 tree had only ivy and 1 (0.06%) tree had rootrot (Figure 4.20).

1050 (68.18%) trees were seen not to be in conflict with any built infrastructure. 296 (19.22%) trees were found to be in conflict with streetlights, 171 (11.10%) trees in conflict with telephone lines, 19 (1.23%) trees in conflict with power lines, 2 (0.12%) trees in conflict with traffic lights, 1 (0.06%) tree in conflict with a street camera and 1 (0.06%) tree in conflict with a wall (Figure 4.21).

1050 (68.18%) Jacaranda street trees were found to be growing in residential areas, 186 (12.07%) trees in commercial areas, 139 (9.02%) trees in industrial areas, 72 (4.67%) trees in areas with mixed zoning, industrial and residential, 20 (1.29%) trees in areas with both industrial and commercial activities and 18 (1.16%) trees growing in areas zoned as both commercial and residential (Figure 4.22)

771 (50.6%) Jacaranda street trees were seen to be growing on surfaces with just bare soil, 466 (30.25%) trees on surfaces with grass, 301 (19.54%) trees on paved surfaces and 2 (0.12) trees on surfaces with ivy (Figure 4.23).

Table 4.16: Number of trees affected by pests and diseases.

| | **Diseases and Pests** | **No. of trees** | **%** |
|---|---|---|---|
| 1 | None | 997 | 64.7 |
| 2 | Strangler | 13 | 0.84 |
| 3 | Ivy | 1 | 0.06 |
| 4 | Termites and Ivy | 3 | 0.19 |
| 5 | Ants | 225 | 14.61 |
| 6 | Termites | 264 | 17.14 |
| 7 | Termites and Ants | 36 | 2.33 |
| 8 | Rootrot | 1 | 0.06 |

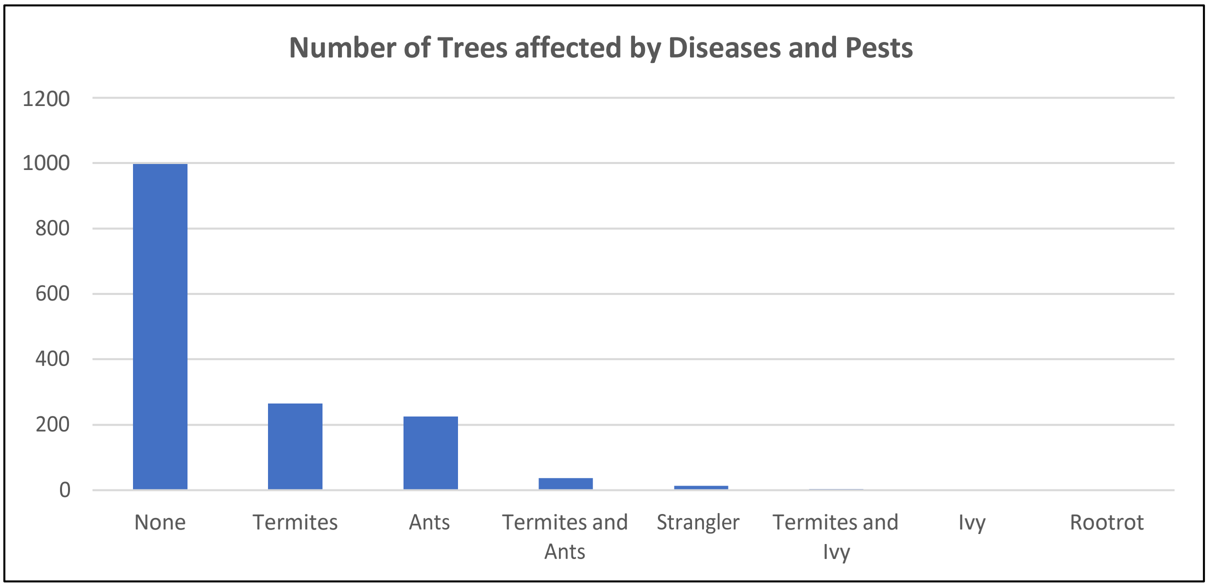


Figure 4.20: Number of trees affected by diseases and pests

Table 4.17: Number of trees in conflict with built infrastructure

| | **Type of Infrastructure in Conflict** | **No. of Tree** | **%** |
|---|---|---|---|
| 1 | Traffic Lights | 2 | 0.12 |
| 2 | None | 1050 | 68.18 |
| 3 | Streetlight | 296 | 19.22 |
| 5 | Telephone line | 171 | 11.10 |
| 6 | Power Line | 19 | 1.23 |
| 7 | Street camera | 1 | 0.06 |
| 8 | Wall | 1 | 0.06 |

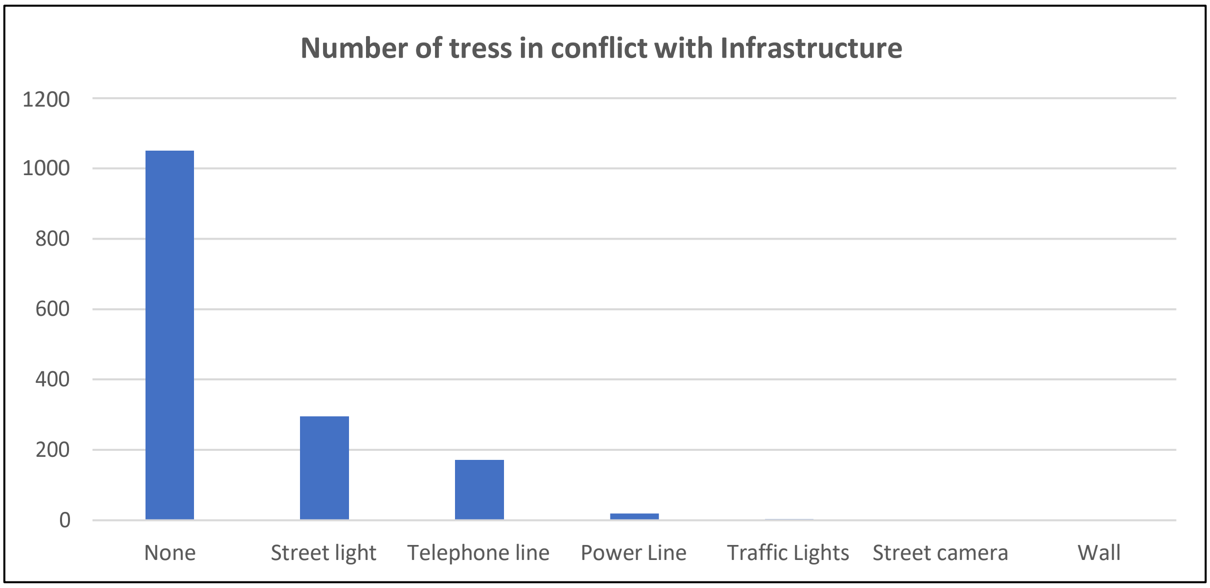


Figure 4.21: Number of trees in conflict with the various built infrastructure.

Table 4.18: Number of trees in the various municipal zones.

| | Zoning | No. of trees | % |
|---|---|---|---|
| 1 | Residential | 1050 | 68.18 |
| 2 | Commercial and Residential | 18 | 1.16 |
| 3 | Commercial | 186 | 12.07 |
| 4 | Industrial | 139 | 9.02 |
| 5 | Commercial and Industrial | 20 | 1.29 |
| 6 | Industrial and Residential | 72 | 4.67 |

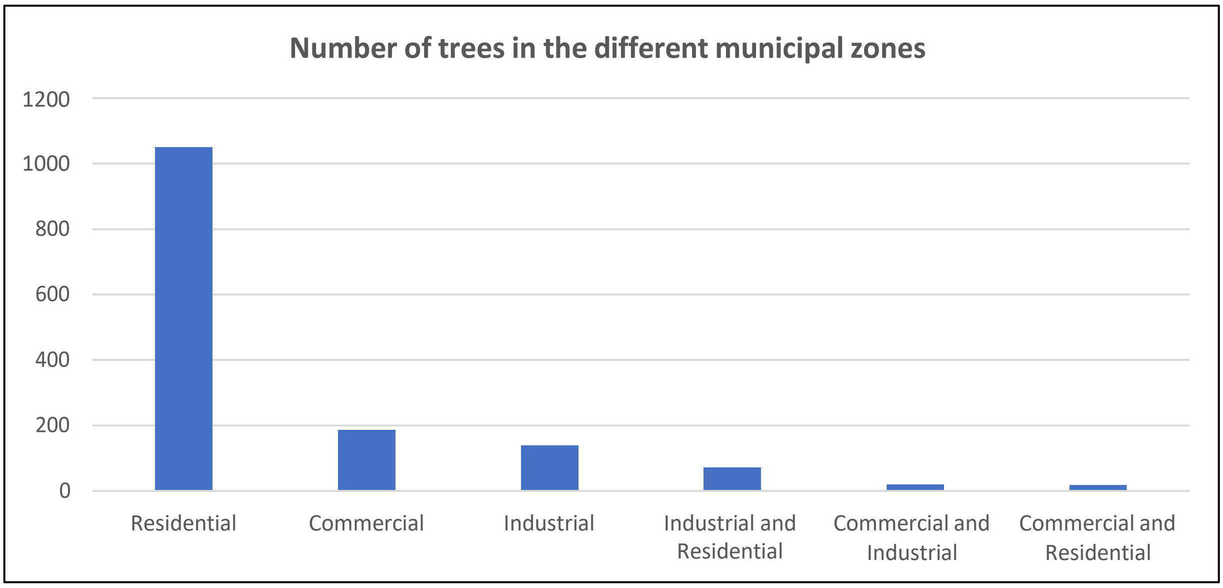


Figure 4.22: Bar Graph showing the number of trees growing in the various municipal zones.

Table 4.19: Number of trees growing on the various ground surfaces.

| | Area where tree is planted | No. of trees | % |
|---|---|---|---|
| 1 | Grass | 466 | 30.25 |
| 2 | Paved | 301 | 19.54 |
| 3 | Ivy | 2 | 0.12 |
| 4 | Sand | 771 | 50.06 |

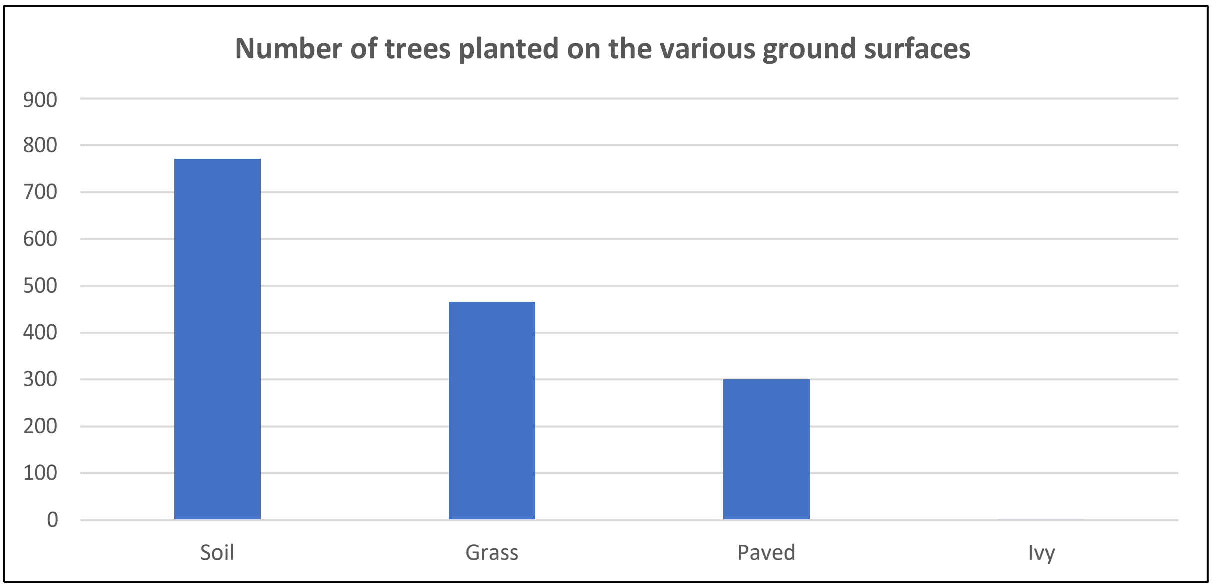


Figure 4.23: Number of trees surrounded by the various ground surfaces.

# CHAPTER 5: DISCUSSION

## 5.1. Introduction

A total number of 1 540 Jacaranda street trees were measured in 72 of the 73 suburbs that were measured in the baseline study. Simon Vermooten in Samcor Park was not measured in this study as the Jacaranda trees measured in the baseline study have since been replaced with a different species. It was expected that the largest stem circumference measurements and subsequently the highest Carbon values would occur in the oldest, established suburbs in the City of Tshwane, it was not the case in all instances due to some of the trees being replaced in these suburbs.

## 5.2. Standing Carbon Stock

The standing carbon stock looks at how much carbon and carbon dioxide equivalent has been stored by the trees in each suburb at the time of measurement (i.e., in 2004 and in 2019). The following sections discuss the highest and the lowest carbon and carbon dioxide equivalent values in this study and how these values compare to those measured in the baseline study.

### 5.2.1. Mean Stem Circumference

In the baseline study suburbs with the highest mean stem circumference at breast height were Asiatic Bazaar, Laudium, Claremont and Colbyn. These suburbs had stem circumference values of 1687mm, 1671mm, 1644mm and 1616mm, respectively. In this study the mean stem circumference for these suburbs was 2115mm (an increase of 428mm and an average increase of 29mm per year since 2004), 1992mm (an increase of 321mm and an average increase of 21mm per year since 2004), 1995mm (an increase of 351mm and an average increase of 23mm per year since 2004) and 1994mm (an increase of 378mm and an average increase of 25mm per year since 2004). In the baseline study suburbs with the lowest mean stem circumference at breast height were Elardus Park, Hestea Park, Newlands and Wingate Park. These suburbs had stem circumference values of 323mm, 278mm, 213mm and 195mm, respectively. In this study the mean stem circumference for these suburbs was 958mm (an increase of 635mm and an average increase of 42mm per year since 2004), 2369mm (an increase of 2091mm and an average increase of 139mm per year since

2004), 1287mm (an increase of 1074mm and an average increase of 72mm per year since 2004) and 1363mm (an increase of 1168 and an average increase of 78mm per year since 2004) respectively. Other suburbs that saw a notable increase of the mean stem circumference at breast height were Erasmuskloof (from 323mm in 2004 to 958mm in 2019) Faerie Glen (from 522mm in 2004 to 1206mm in 2019), Mayville (419mm in 2004 to 2019mm in 2019), Moreleta Park (from 624mm in 2004 to 2019mm in 2019), Philip Nel (from 520mm in 2004 to 1333mm in 2019) and Saulsville (from 340mm in 2004 to 1216mm in 2019). This is due to the presence of multiple stemmed trees measured in these suburbs.

In this study (2019) suburbs with the highest mean stem circumference at breast height were Hestea Park, Riviera, Sinoville and Rietondale. These suburbs have stem circumference values of 2369mm, 2249mm, 2200mm, and 2115mm, respectively. In the baseline study these suburbs had a mean stem circumference at breast height of 278mm (an increase of 2091mm by 2019 and an increase of 139mm per year since 2004), 1497mm (an increase of 752mm over 15 years and an increase of 50mm per year since 2004), 1532mm (an increase of 668mm by 2019 and an increase of 45mm per year since 2004) and 1400mm (an increase of 715mm over 15 years and an increase of 48mm per year since 2004) respectively. In this study suburbs with the lowest mean stem circumference at breast height were Eastwood, Erasmusrand, Elardus Park and Meyers Park. These suburbs had mean stem circumference values of 1098mm (a reduction of 71mm by 2019 and a reduction of 5mm per year since 2004), 773mm (an increase of 202mm by 2019 and an increase of 13mm per year since 2004), 323mm (an increase of 635mm by 2019 and an increase of 42mm per year since 2004) and 1021mm (a reduction of 131mm by 2019 and a reduction of 9mm per year). It is assumed that this reduction is due to the replacing of some trees since the baseline study. Therefore, the trees are younger and smaller than those measured in the baseline study.

### 5.2.2. Total Carbon

The highest quantities of total standing carbon stock in the baseline study occurred in Pretoria Central, Brooklyn, Waterkloof and Sunnyside with an estimated 1 379.03 t C (11.297% of the total quantity of carbon), 1 195.35 t C (9.79% of the total quantity of carbon), 801.35 t C (6.565% of the total quantity of carbon) and 788.65 t C (6.46% of the total quantity of carbon) respectively. In this study these suburbs had an estimated total carbon of 1 380.68 t C (an increase of 2 tonnes and an increase of 0.133 tonnes per year since 2004), 1 048.53 t C (a reduction of 147 tonnes and an average reduction of 10 tonnes per year since 2004), 797.76 t C (a reduction of 4 tonnes and an average reduction of 0.266 tonnes per year since 2004) and 724 t C (a reduction of 64 tonnes and a reduction of 4 tonnes per year). The lowest quantities of total standing carbon in the occurred in Mayville, Hestea Park, Newlands and Wingate Park with an estimated 1.15 t C (0.009% of the total carbon quantity), 0.91 t C (0.007% of the total carbon quantity), 0.34 t C (0.003% of the total carbon quantity) and 0.34 t C (0.003% of the total carbon quantity) respectively. In this study these suburbs had an estimated total standing carbon of 8.25 t C (an increase of 7 tonnes and an increase of 0.46 tonnes per year since 2004), 75.11 t C (an increase of 74 tonnes and an increase of 4.93 tonnes per year since 2004), 12.41 t C (an increase of 12.07 tonnes and an increase of 0.80 tonnes per year since 2004) and 15.57 t C (an increase of 15.23 tonnes and an increase of 1.01 tonnes per year since 2004).

In this study the highest quantities of the total standing carbon stock occurred in Pretoria Central, Brooklyn, Arcadia and Villiera with an estimated 1380.68 t C (8.59% of the total quantity of carbon), 1124 t C (7.00% of the total quantity of carbon), 1048.53 t C (6.52% of the total quantity of carbon) and 846.54 (4.87% of the total quantity of carbon) respectively. In the baseline study the estimated total standing carbon for these suburbs was 1 379.03 t C (an increase of 1.65 tonnes in 2019 and an increase of 0.12 tonnes per year since 2004), 708.77 t C (an increase of 415.72 tonnes in 2019 and an increase of 27.71 tonnes per year since 2004), 1 195.30 t C (a reduction of 146.77 tonnes by 2019 and a reduction 7.8 tonnes per year since 2004) and 552.80 t C (an increase of 293.74 tonnes by 2019 and an increase of 19.58 tonnes per year since 2004). The lowest quantities of carbon in this study occurred in Wingate Park, Jan Niemand Park, Newland and Mayville with an estimated 15.57 t C (0.09% of the total quantity of carbon), 12.64 t C (0.07% of the total quantity of carbon), 0.12.44 t C (0.07% of the total quantity of carbon) and 8.25 t C (0.05% of the total quantity of carbon) respectively. In the baseline study the estimated total standing carbon for these suburbs was 0.34 t C (an increase of 15.23 tonnes by 2019 and an increase of 1.01 tonnes per year since 2004), 5.37 t C (an increase of 6.27 tonnes by 2019 and an increase of 0.41 tonnes per year since 2004), 0.34 t C (an increase of 12.1 tonnes by 2019 and an average increase of 0.80 tonnes per year since 2004) and 1.15 t C (an increase of 7.1 tonnes by 2019 and an increase of 0.47 tonnes per year since 2004) respectively

The total carbon quantity of all the suburbs where Jacaranda street trees were measured (73 suburbs) was estimated at 12 207.372 t C in the baseline study. The adjusted total carbon quantity for all suburbs (72 suburbs, without Samcor Park, due to the replacement of the Jacaranda trees with a different species), was 12 170.92 t C This is done in line with the adjustment done in the baseline study. The total carbon quantity of all the suburbs where Jacaranda street trees were measured in this study (72 suburbs) was estimated at 17 383.89 t C.

The estimated total carbon quantity for all the suburbs (73 suburbs) measured in the baseline study was 12 207.37 t C. In this study the estimated total carbon quantity for all the suburbs (72 suburbs) measured was 16 060.69 t C (23.9% increase since the baseline study) This value.

### 5.2.3. Total Carbon Dioxide Equivalents

The highest estimated total carbon dioxide equivalent value that had been stored in the trees at the time of measurement in the baseline study occurred in Pretoria Central, Brooklyn, Waterkloof and Sunnyside with an estimated 5 061.067 t $CO_2$ eq, 4 386.939 t $CO_2$ eq, 2 940.988 t $CO_2$ eq and 2 894.349 t $CO_2$ eq, respectively. The estimated total carbon dioxide equivalent values for these suburbs in this study were 5 067.12 t $CO_2$ eq (an increase of 6.06 tonnes and an average increase of 0.40 tonnes per year since 2004), 3 848.11 t $CO_2$ eq (a reduction of 538.82 tonnes and an average reduction of 35.92 tonnes per year since 2004), 2 927.80 t $CO_2$ eq (a reduction of 13.18 tonnes and an average reduction of 0.87 tonnes per year) and 2 656.87 t $CO_2$ eq (a reduction of 238.34 tonnes and a reduction of 15.8 tonnes per year) respectively. The lowest carbon dioxide equivalent in the baseline study occurred in Mayville, Hestea Park, Newlands and Wingate Park with an estimated 4.24 t $CO_2$ eq, 3.35 t $CO_2$ eq, 1.27 t $CO_2$ eq and 1.26 t $CO_2$ eq, respectively. In this study the estimated carbon dioxide equivalent values for these suburbs were 30.27 t $CO_2$ eq (an increase of 26.03 tonnes and an increase of 1.73 tonnes per year since 2004). 275.66 t $CO_2$ eq (an increase of 272.31 tonnes and of 1.73 an increase of 18.15 tonnes per year since 2004), 45 t $CO_2$ eq 9 an increase of 2.95 tonnes and an increase of 2.95 tonnes per year since 2004) and 57.16 t $CO_2$ eq (an increase of 3.72 tonnes and an increase of 3.72 tonnes a year since 2004) respectively.

In this study highest estimated total carbon dioxide equivalent values that had been stored in the trees at the time of measurement occurred in Pretoria Central, Arcadia, Brooklyn and Villiera with an estimated 5 067.12 t $CO_2$ eq, 4 126.80 t $CO_2$ eq, 3 848.11 t $CO_2$ eq and 3 106.80 t $CO_2$ eq, respectively. The estimated carbon dioxide equivalent values for these suburbs in the baseline study were 5 061.06 t $CO_2$ eq (an increase of 6.06 tonnes by 2019 and an increase of 0.40 tonnes a year since 2004), 2 601.20 t $CO_2$ eq (an increase of 1 526.6 tonnes by 2019 and an increase of 101.70 tonnes per year since 2004), 4 386.93 t $CO_2$ eq (a reduction of 538.82 tonnes by 2019 and a reduction of 35.92 tonnes per year since 2004) and 2 028.79 t $CO_2$ eq (an increase of 1 087.01 tonnes by 2019 and an increase of 71.86 tonnes per year since 2004) respectively. It is also important to note the total carbon dioxide values of Waterkloof and Sunnyside which had both decreased in this study. The estimated values thereof in this study were 797.76 t $CO_2$ eq compared to 801.35 t CO2 eq in the baseline study and 724.21 t $CO_2$ eq, compared to 788.65 t $CO_2$ eq in the baseline study, respectively. This is a reduction of 3.35 tonnes (reduction of 0.23 per year since 2004) in Waterkloof and 64,44 tonnes (reduction of 4.29 tonnes per year since 2004) in Sunnyside since the baseline study. Suburbs with the lowest estimated total carbon dioxide equivalent values that had been stored in the trees at the time of measurement in this study occurred in Wingate Park, Jan Niemand Park, Newlands and Mayville with an estimated 57.16 t $CO_2$ eq, 46.42 t $CO_2$ eq, 45.56 t $CO_2$ eq and 30.27 t $CO_2$ eq, respectively. The lowest estimated total carbon dioxide equivalent values for these suburbs in the baseline study were 1.26 t $CO_2$ eq (an increase of 55.9 tonnes by 2019 and an increase of 3.72 tonnes per year since 2004), 19.72 t $CO_2$ eq (an increase of 26.7 tonnes by 2019 and an average increase of 1,78 tonnes per year since 2004),

1.27 t $CO_2$ eq (an increase of 44.29 tonnes by 2019 and an average increase of 2.95 tonnes per year since 2004) and 4.24 t $CO_2$ eq (an increase of 26.03 tonnes since 2019 and an average increase of 1.73 tonnes per year since 2004) respectively.

According to Köhl, Neupane and Lotfiomran (2017) and Stephen, Das, Condit, Russo, Baker, Beckman, Coomes, Lines, Morris, Rüger, Alvarez, Blundo, Bunyavejchewin, Chuyong, Davis, Duque, Ewango, Flores, Franklin, Grau, Hao, Harmon, Hubbel, Kenfack, Lin, Makana, Malizia, Manlizia, Pabst, Pongpattananurak, Su, Tan, Thomas, Mantgen, Wang, Wiser and Zavala (2014) the rate of carbon accumulation increases with the tree size and age. Older and bigger trees accumulate more carbon than smaller, younger trees (Köhl et al, 2017; Stephen et al, 2014). The slight drop in total carbon and subsequently total carbon dioxide equivalent amounts absorbed in the trees measured in this study in suburbs such as Sunnyside, Waterkloof and Brooklyn can therefore be attributed to the replacing of some Jacaranda trees measured in the baseline study. This happened due to some trees becoming old and dying and due to road infrastructure expansion as the municipality grew and advanced. Some of the older suburbs such as Pretoria Central only saw a small increase in the carbon and carbon dioxide equivalent stored. This is also attributed to the replacing of older trees with younger ones. Hestea Park saw the largest total carbon and subsequently total carbon dioxide equivalent increase in this study, adding 2 216 tonnes of $CO_2$ eq since the baseline study. The reason put forward for this is that the Jacaranda tree population in Hestea Park has remained undisturbed since the baseline study (i.e., no trees were replaced) therefore allowing the total carbon dioxide equivalent values to increase undisturbed. Meyers Park experienced the largest decrease of total carbon in this study since 2004. The total carbon value fell by 30.18 tonnes since the baseline study where the total carbon was 48.85 t C. This is 61.6% decrease of the total carbon amount in that suburb. It is assumed that this is due to the replacing of a substantial number of trees measured in the baseline study.

### 5.3. Monetary Values

The baseline study used a hypothetical market price of one tonne of $CO_2$eq is equal to US$10 to calculate the dollar value. The baseline study then determined the Rand value of $CO_2$eq by using the US$1 is equal to R6.59 conversion based on the exchange rate at the time. In the current study the Rand value of the $CO_2$eq was calculated using the 1 tonne of $CO_2$eq being equal to R120 conversion as stipulated in the Carbon Tax Bill (2010) provided by the South African National Treasury. The US dollar values were calculated by using the US$1 is equal to R15 exchange rate (businesstech.co.za, 2018).

#### 5.3.1. Total Carbon Dioxide Equivalent Carbon Tax Rand values

The largest estimated total carbon dioxide equivalent that had been stored in the trees at the time of measurement in the baseline study occurred in Pretoria Central, Brooklyn, Waterkloof and Sunnyside with an estimated 5 061.067 t $CO_2$ eq, 4 386.939 t $CO_2$ eq, 2 940.988 t $CO_2$ eq and 2 894.349 t $CO_2$ eq, respectively. The estimated Rand values for each of the suburbs with the largest quantities were R333 524.29 (11.97% of the total value), R289 099.26 (9.792% of the total value), R193 811.08 (6.565% of the total value) and R190 737.60 (6.460% of the total value) respectively. In this study these suburbs had an estimated total carbon dioxide equivalent value of 5 067.12 t $CO_2$ eq, 3 848.11 t $CO_2$ eq, 2 927.80 t $CO_2$ eq and 2 656.87 t $CO_2$ eq respectively. The estimated Rand values thereof were R608 055.41 (8.59% of the total value, an estimated increase of R274 531.12 since in 2019 and an increase of R18 302.07 per year since 2004), R461 774.31 (6.52% of the total value, an increase of R172 675.05 in 2019 and an increase of R11 511.67 per year since 2004), R351 336.24 (4.58% of the total value, an increase of R157 525.16 in 2019 and an increase of R10 501.67 per year since 2004) and R318 945.40 (4.50% of the total value, an increase of R128 207.80 in 2019 and an increase of R8 547.18 per year since 2004) respectively. The largest estimated total carbon dioxide quantities at the time of measurement.in this study occurred in Pretoria Central, Arcadia, Brooklyn and Villiera with an estimated 5067.12 t $CO_2$ eq, 4126.80 t $CO_2$ eq, 3848.11 t $CO_2$ eq and 3106.80 t $CO_2$ eq, respectively. The estimated Rand values for each of the suburbs with the largest quantities were R608 055.41 (8.59% of the total rand value), R495 216.19 (7.00% of the total rand value), R461 774.31 (6.52% of the total value) and R372 816.84 (4.87% of the total value). In the baseline study these suburbs had estimated total carbon dioxide quantities of 5061.06 t $CO_2$ eq, 2601.20 t $CO_2$ eq, 4386.93 t $CO_2$ eq and 2028.79 t $CO_2$ eq. The estimated Rand values for these suburbs in the baseline study were R333 524.29 (11.29% of the total, an increase of R274 531.12 by 2019 and an average increase of R18 302.07 per year since 2004), R171 419.59 (5.80% of the total, an increase of R322 796.6 in 2019 and an increase of R21 519.77 per year since 2004), R289 099.26 (9.79% of the total, an increase of R172 675.05 in 2019 and an increase of R11 511.67 per year since 2004) and R133 697.70 (4.52% of the total, an increase of R239 119.14 in 2019 and an increase of R15 941.27 per year since 2004) respectively.

The lowest estimated carbon dioxide equivalent quantities at the time of measurement in the baseline study occurred in Mayville, Hesta Park, Newlands and Wingate Park with an estimated 1.15 t $CO_2$ eq, 0.91 t $CO_2$ eq, 0.34 t $CO_2$ eq and 0.34 t $CO_2$ eq respectively. The estimated Rand values for each of the suburbs with the lowest quantities were R279.51 (0.009% of the total), R220.87 (0.007% of the total), R83.77 (0,003% of the total) and R83.10 (0.003% of the total) respectively. In this study the estimated carbon dioxide for these suburbs was 30.27 t $CO_2$ eq, 275.60 t $CO_2$ eq, 45.56 t $CO_2$ eq and 57.16 t $CO_2$ eq. The estimated Rand values thereof were R3 633.52 (0.05% of the total, an increase of R3 354.01 and increase of R223.60 per year since 2004), R33 080.17 (0.46% of the total, an of R32 859.3 and an increase of R2 190.62 per year since 2004), R5 467.44 (0.07% of the total, an increase of R5 383.67 and an increase of R358.91 per year since 2004) and R6 859.55 (0.09% of the total, an increase of R6 776.45 and an increase of R451.76 per year since 2004) respectively. In this study the lowest estimated carbon dioxide equivalent quantities at the time of measurement occurred in Wingate Park, Jan Niemand Park, Newlands and Mayville with estimated values of 57.16 t $CO_2$ eq, 46.42 t $CO_2$ eq, 45.56 t $CO_2$ eq and 30.27 t $CO_2$ eq, respectively. The estimated Rand values were R6 859.55 (0.09% of the total), R5 570.48 (0.07% of the total), R5 467.44 (0.07% of the total) and R3 633.52 (0.05% of the total) respectively. In the baseline study the estimated carbon dioxide for these suburbs was 1.26 t $CO_2$ eq, 19.72 t $CO_2$ eq, 1.27 t $CO_2$ eq and 4.24 t $CO_2$ eq, respectively. The Rand values thereof were R83.10 (0.003% of the total, an increase of R6 776.45 in 2019 and an increase of R451.76), R1 300.95 (0.04% of the total, an increase of R4 270.43 in 2019 and an average increase of R284.69 per year since 2004), R83.77 (0.003% of the total, an increase of R5 383.67 in 2019 and an increase of R358.91 per year since 2004) and R279.51 (0.009% of the total, an increase of R3 354.01 in 2019 and an increase of R223.60 per year since 2004) respectively.

In the baseline study the total quantity of carbon for all the suburbs in Tshwane (114 suburbs) was estimated at 12 709.241 t C. This total was employed in this study upon confirmation that no other census was done on Jacaranda street trees post the baseline study. in the baseline study making the estimated total carbon quantity of 11 438.317 t C for the City of Tshwane ‘s Jacaranda street trees. In this study the adjusted total carbon quantity was 15 645.51 t C.

According to Stoffberg (2006) a discrepancy of a minus 10% of the trees was observed during the fieldwork, therefore, the total values were adjusted accordingly. The estimated Rand value in the baseline study was therefore R2 766 391. To calculate the US$ rate in this study, an exchange rate of 1 US dollar is equal to R15 was used (businesstech.co.za, 2018). The estimated total US dollar amount was US$510 391.27. To calculate the ZAR amount, the 1 tonne of carbon is equal to R120 exchange rate was used (South African National Treasury, 2010). The estimated total amount was R7 073 128 with an adjusted value of R6 365 815.68. The Carbon Tax bill played a vital role in increasing the monetary value of Jacaranda street trees in the City of Tshwane since the baseline study.

## 5.4. Carbon Sequestration between 2004 and 2019

Carbon sequestration refers to how much carbon and carbon dioxide equivalent values have been sequestrated in the period between the baseline study (2004) and this study (2019). The following sections discuss the highest and the lowest differences of carbon and carbon dioxide sequestration in the 15-year period between the baseline study and the current study.

### 5.4.1. Total Carbon and Total Carbon Dioxide Equivalent values between 2004 and 2019

Suburbs that had the highest total carbon sequestrated since 2004 were Arcadia (415.69 t C), Riviera (352 t C), Rietondale (344.79 t C) and Villiera (293.74 t C). The highest total carbon dioxide equivalent valued sequestrated since 2004 in these suburbs were 1 525.60 t $CO_2$ eq, 1 292.54 t $CO_2$ eq, 1 265.38 t $CO_2$ eq and 1078.01 t $CO_2$ eq. Suburbs that had the highest net reduction in the total carbon sequestrated since 2004 were Brooklyn (reduction of -146.81 t C), Pretoria West (reduction of -103.95 t C), Sunnyside (reduction of -64.43 t C) and Meyers Park (reduction of -30.12 t C). The highest reduction of the total carbon dioxide equivalent values for these suburbs were 538.81 t $CO_2$ eq, 381.52 t $CO_2$ eq, 236.46 t $CO_2$ eq and 110.55 t $CO_2$ eq, respectively.

## 5.5. Growth Environment

997 trees were not affected by any pests or diseases. Combined, 489 trees had termites and ants living on and around then. The trees showed no signs of stress due to the presence of these pests. Only one tree was seen to have fruiting bodies indicative of the presence of the Garnoderma fugus that causes root rot. Even so, the tree showed no visible signs of illness due to the presence of the fungus. 1050 trees had no conflict with infrastructure. 296 trees had streetlights installed close to

them. These trees had however been pruned to allow for the presence of streetlights and their electrical lines. 1050 trees were found to be growing in residential areas. 771 trees were seen to be growing on surfaces with just soil and no other vegetation. It was assumed that this would affect the trees' ability to absorb water negatively as the bear surface would increase run off, however the Jacaranda trees growing under these conditions showed no signs of stress and showed no conflict with infrastructure. 296 trees had streetlights installed close to them. These trees had however been pruned to allow for the presence of streetlights and their electrical lines. 1050 trees were found to be growing in residential areas. 771 trees were seen to be growing on surfaces with just soil and no other vegetation. It was assumed that this would affect the trees' ability to absorb water negatively as the bear surface would increase run off, however the Jacaranda trees growing under these conditions showed no signs of stress.

### 5.6. Carbon Trading

As a signatory to the Kyoto Protocol, South Africa is obligated to reduce GHG emissions (Promethium Carbon, 2014). The Kyoto Protocol provides three Market Mechanisms amongst which the Clean Development Mechanism (CDM) is perfectly positioned to assist developing countries like South Africa to reduce their emissions (Promethium Carbon, 2014). The CDM is voluntary, project-based mechanism under Article 12 of the Kyoto Protocol (Promethium Carbon, 2014). The mechanism has a dual purpose of reducing emissions and contributing towards sustainable development (Promethium Carbon, 2014). However, the carbon sequestrated by Jacaranda street trees in the City of Tshwane cannot be used to trade carbon because the trees are not registered under the project registry and most of them were planted before the Kyoto Protocol was ratified in 1997. The trees were also planted by the municipality as a day-to-day activity and do not provide any additional benefits to reducing GHG emissions.

Similarly, to the baseline study it must be stated that the value of Jacaranda street trees resides mostly in their cultural heritage in the city. However, their role in mitigating the impacts of climate change through carbon sequestration must also be recognized. Although no new Jacaranda trees may be planted by law, through the establishment of the Carbon Tax Bill, which states that a tonne of carbon has the value of R120, the trees can now be afforded a monetary value which enhances the argument to protect the remaining Jacaranda street trees in the City of Tshwane.

## 5.7. Recommendations

A similar study on other species of native trees in South Africa would also enhance the importance of protecting and planting more trees in the country. The Jacaranda tree has been identified as a non-reproductive host of the ambrosia beetle which carries the *Fusarium euwallacea* fungus. The effect of this beetle on the Jacaranda trees in the City of Tshwane is not yet established. It is therefore recommended that a study be undertaken to determine if the beetle has infested the Jacaranda trees in the City of Tshwane. The cultural value of the Jacaranda tree has not been determined. It is also recommended that this should be studied and quantified in monetary terms.

## 5.8. Conclusion

The highest quantities of total standing carbon stock in the baseline study occurred in Pretoria Central, Brooklyn, Waterkloof and Sunnyside with an estimated 1 379.03 t C (11.297% of the total quantity of carbon), 1 195.35 t C (9.79% of the total quantity of carbon), 801.35 t C (6.565% of the total quantity of carbon) and 788.65 t C (6.46% of the total quantity of carbon) respectively. In this study the highest quantities of the total standing carbon stock occurred in Pretoria Central, Brooklyn, Arcadia and Villiera with an estimated 1380.68 t C (8.59% of the total quantity of carbon), 1124 t C (7.00% of the total quantity of carbon), 1048.53 t C (6.52% of the total quantity of carbon) and 846.54 (4.87% of the total quantity of carbon) respectively. The mean total carbon per tree for all the suburbs where Jacaranda street trees were measured in the baseline study was estimated at 0.378 t C. In this study the mean t carbon per tree for all the suburbs where Jacaranda street trees were measured (72) was an estimated 0.455 t C. In the baseline study the total carbon for all the suburbs (72 without Samcor Park) was 12 673.02. According to the baseline study some discrepancies were observed in the number of trees suggested. To account for such discrepancies, an adjustment of -10% was employed resulting in the value of 11 405.72 t C. In this study the total carbon for all the suburbs (72) was 16 060.69 t

C. The adjusted value was 14 454.62 t C. The highest estimated total carbon dioxide equivalent value that had been stored in the trees at the time of measurement in the baseline study occurred in Pretoria Central, Brooklyn, Waterkloof and Sunnyside with an estimated 5 061.067 t $CO_2$ eq, 4 386.939 t $CO_2$ eq, 2 940.988 t $CO_2$ eq and 2 894.349 t $CO_2$ eq, respectively. In this study highest estimated total carbon dioxide equivalent values that had been stored in the trees at the time of measurement occurred in Pretoria Central, Arcadia, Brooklyn and Villiera with an estimated 5 067.12 t $CO_2$ eq, 4 126.80 t $CO_2$ eq, 3 848.11 t $CO_2$ eq and 3 106.80 t $CO_2$ eq respectively the mean carbon dioxide equivalent for all suburbs where Jacaranda street trees (72) was an estimated 1.387 t $CO_2$ eq in the baseline study. In this study the estimated value was 223.06 t $CO_2$ eq. The total carbon dioxide equivalent value for all suburbs (72 without Samcor Park) in the baseline 46 509.97 t $CO_2$ eq. The adjusted value was 41 858.98 t $CO_2$ eq. In this study the total carbon dioxide equivalent vale for all suburbs (72) was 58 158.85 t $CO_2$ eq. The adjusted value was 52 342.97.

The estimated total Rand value for all the suburbs (72 without Samcor Park) in the baseline study was R2 757 630.37. In this study the total Carbon Tax Rand value for all the suburbs (72) was R7 073 128 and the adjusted value was R6 365 815. The Carbon Tax bill played a vital role in increasing the monetary value of Jacaranda street trees in the City of Tshwane since the baseline study. A similar study on other species of native trees in South Africa would also enhance the importance of protecting and planting more trees in the City of Tshwane.

From the growing conditions presented in this study, it can be said that the Jacaranda street trees in the City of Tshwane are healthy and thriving. However, it must be stated that the trees will need to be monitored as they have been identified as one of the hosts of the ambrosia beetle which carries the *Fusarium euwallacea* fungus.

Although there were net carbon fluctuations in individual suburbs, the Jacaranda street trees in the City of Tshwane continue to mitigate climate change. This study provides an incentive for the municipality to continue maintaining and preserving the urban forest in the City of Tshwane.

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